HAMILTON STANDARD Division of UNITED TECHNOLOGIES

SVHSER 7077

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LIGHTWEIGHT LONG LIFE HEAT EXCHANGER

FINAL REPORT

BY

EARL K. MOORE

PREPARED UNDER CONTRACT NAS 9-14494

BY

HAMILTON STANDARD
DIVISION OF UNITED TECHNOLOGIES CORPORATION
WINDSOR LOCKS, CONNECTICUT

FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

JULY, 1976

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ABSTRACT

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This report describes the design, fabrication, and test of a heat exchanger intended to be a direct replacement for the Shuttle ECS condensing heat exchanger. The objective was to achieve a weight reduction of at least forty percent.

FOREWORD

This report has been prepared by the Hamilton Standard Division of the United Technologies Corporation for the National Aeronautics and Space Administration, Lyndon B. Johnson Space Center in accordance with the requirements of Contract NAS 9-14494, Lightweight Long Life Heat Exchanger. This report covers all of the work accomplished during the period of the contract, January 13, 1975 to October, 1976. The basic objective of the program was to design, manufacture, and test a Shuttle orbiter flight configuration lightweight long life heat exchanger weighing no more than 60 percent of an equivalent stainless steel heat exchanger. Personnel responsible for the conduct of this program were Mr. F. H. Greenwood and Mr. H. Brose, Program Managers, and Mr. E. K. Moore, Program Engineer. Appreciation is expressed to Mr. B. S. Blum of the Hamilton Standard Materials Department and Mr. G. Coleman, Manufacturing Engineer, and to Mr. Frank Collier, Technical Monitor for NASA/JSC.

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SUMMARY

A Shuttle orbiter flight configuration aluminum heat exchanger was designed, fabricated, and tested. The heat exchanger utilized aluminum clad titanium composite parting sheets for protection against parting sheet pin hole corrosion. The heat exchanger, which is fully interchangeable with the Shuttle condensing heat exchanger, includes slurpers (a means for removing condensed water from the downstream face of the heat exchanger), and both the core air passes and slurpers were hydrophilic coated to enhance wettability. The test program included performance tests which demonstrated the adequacy of the design and confirmed the predicted weight savings.

Calculations and data pertaining to this program were originated in U.S. customary units and then converted to S.I. units.

INTRODUCTION

In 1971, Hamilton Standard initiated an Internal Research and Development (IR&D) program to develop a lightweight long life heat exchanger. The basis of achieving lightweight combined with long life was the development of a composite aluminum-titanium sheet material capable of withstanding pitting corrosion which may occur when aluminum is exposed to wet air. The work showed that a weight savings of forty percent of a comparable stainless steel heat exchanger could be realized. The IR&D work also included extensive testing to demonstrate that aluminum is compatible with a stainless steel water loop. It also showed that interface problems, aluminum to stainless steel, should not exist.

As a result of the success of the IR&D program, the NASA initiated Contract NAS 9-13552 to evaluate the potential of a Lightweight Long Life Heat Exchanger for the Shuttle ECS. During that program, the manufacture of composite sheets was refined, and a full scale Shuttle type condensing heat exchanger was designed, fabricated, and tested, demonstrating the suitability of the composite sheet approach for long life, lightweight application. The NASA then established Contract NAS 9-14494 to design, fabricate, and test a flight representative lightweight heat exchanger to be directly interchangeable with the Shuttle stainless steel condensing heat exchanger. The aluminum heat exchanger met the requirements to be at least 40% lighter than the equivalent stainless steel unit.

CONCLUSIONS

A lightweight long life aluminum heat exchanger, fully interchangeable with the Shuttle condensing heat exchanger, has been designed and manufactured with production type tools and tested and shown to meet Shuttle performance requirements and the weight reduction expected.

RECOMMENDATIONS

It is recommended that the heat exchanger manufactured during this program be utilized for testing by the NASA to demonstrate the long term compatibility of an aluminum heat exchanger in a stainless steel water system.

DISCUSSION

The discussion of the program is divided into the several major task areas. These are; Fabrication of Laminates, Design, Heat Exchanger Fabrication, and Test. Each major task represents a major element of the program work breakdown structure.

FABRICATION OF LAMINATES

The procedures for fabricating the composite parting sheets were established during previous IR&D work, were refined during the previous program, and used without change, with one exception, for manufacturing the laminates for this program. The one change was the substitution of chemical cleaning for abrasive cleaning of the titanium foil.

The current heat exchanger design utilizes twenty water passes, each requiring three laminated parting sheets. During the previous program, a yield of 70 percent of the laminates had been realized. By slightly modifying tooling, two parting sheets could be cut from one laminate; and considering that details for three cores were to be fabricated and a feasibility core to be made, the number of laminates to be manufactured was:

$$\frac{20 \times 3 \times 3}{.7 \times 2} + \frac{12 \times 2}{.7 \times 2} = 146$$

Therefore, material for 150 laminates was procured and processed in two groups of 75 laminates each.

Ultrasonic inspection was used to inspect all laminates used and to select samples for destructive examination. The destructive examination, which consisted of 180° bend tests for delamination, showed that only laminates with gross ultrasonic indications would not be suitable for use; and on this basis, less than five percent of all laminates inspected were rejected.

Twelve sheets with various types of indications were used in the fabrication of the feasibility cores discussed later; and in the destructive examination of those cores, no evidence of delamination was found, confirming the adequacy of the ultrasonic inspection process and that the laminate fabrication procedures are successful.

DESIGN OF FLIGHT CONFIGURATION HEAT EXCHANGER

Analytical Study

Although the heat exchanger designed and fabricated during the previous program was designed to Shuttle requirements, changes in those requirements occurred during that program. Therefore, after completing life testing in the previous program, the heat exchanger was subjected to several tests at the changed conditions. Table I shows a sample of the results. The unit met thermal requirements but demonstrated a pressure drop slightly higher than requirements. Further, by the time the current design had begun, requirements had again changed as shown in Table II.

A number of configurations were analyzed in order to optimize the design in terms of envelope, minimum weight, and manufacturing simplicity. The details of the final design are shown in Table III, with the nomenclature used defined in Table IIIA.

The previous configuration, utilizing aluminum fins with a high thermal conductance and, therefore, high fin efficiency had been constructed with the largest practical fin height to achieve minimum weight. With the increase in gas flow rate, fin effectiveness is reduced, and the selection of 1.548 cm (0.645 inch) fins was reviewed to determine if prior conclusions remain valid. The results are shown in Figure 1. Because of the particular balance between fin conductivity and gas conductance in the original design, a high fin was warranted. This conclusion appears to remain valid for the revised condition, although with significantly less magnitude when considering fin heights over approximately 1.2 cm (0.5 inches). The effect of the gas side parting sheet (utilized to separate and support the two fins needed when total height exceeds 1.08 cm (0.450 inches)) is included in this analysis to produce a step weight change. At the higher gas flow rate, Figure 1 shows that a change to lower fin heights is warranted even though fin effectiveness is less.

This change necessitates three additional core configuration changes. Core height is limited by Shuttle envelope, but the fraction of this height consumed by air passages must remain reasonably constant to conform to air pressure drop limitation. Therefore, as gas fin height is reduced, liquid fin height should be proportionately reduced. This reduction increases water pressure drop, but for this design was relieved by reducing the number of cold passes from six to four. The slight loss in performance was regained by increasing cold fin density from 4.7 to 7.1 fins per cm (12 to 18 fins per inch).

Pressure loss calculations indicate that specification requirements are met and are included in Appendix A of this report for reference.

TABLE I

TYPICAL TEST RESULTS

Parameter	Requirement S.I. Units	Requirement U.S. Units	Result S.I. Units	Result U.S. Units
H_2O Flow kg/sec (lb/hr)	0.09	725	0.09	725
H_2O Temperature in °C (°F)	7.0	44.6	7.1	44.8
H_2O Temperature out °C (°F)	15.7	60.3	15.8	60.5
Air Flow kg/sec (lb/hr)	0.176	1398	1.816	1404
Air Temperature in °C (°F)	26.8	80.3	26.9	80.4
Air Temperature out °C (°F)	10.3	50.5	9.9	49.9
Air Delta P H/m^2 (in. H_2O)	199.26	0.8	216.7	0.87
Dew Point in °C (°F)	11.2	52.1	11.1	52
Dew Point out °C (°F)	10.3	50.5	9.4	49

TABLE II

LIGHTWEIGHT LONG LIFE HEAT EXCHANGER DESIGN REQUIREMENTS

Parameter	Original S.I. Units	Original U.S. Units	Current S.I. Units	Current U.S. Units
Outlet Total Pressure kN/m^2 (psia)	101.4	14.7	102.0	14.8
Gas Flow kg/sec (lbs/hr)	0.111	880	0.172	1366
Gas Inlet Temperature °C (°F)	36.1	97	40.0	104
Gas Outlet Temperature °C (°F)	9.74	49.54	10.1	50.1
Inlet Dew Point °C (°F)	16.1	61	14.2	57.6
H_2O Inlet Temperature °C (°F)	4.4	40	6.4	43.5
H_2O Flow kg/sec (lbs/hr)	0.076	600	0.127	1009
Max. Air Side Dry Delta P N/m^2 (in. H_2O)	96.39	0.387	149.45	0.6
Max. Air Side Wet Delta P N/m^2 (in. H_2O)		--	199.26	0.8
Q Sensible Watts (Btu/hr)	2976	10160	5225	17842
Q Latent Watts (Btu/hr)	1074	3667	1028	3509
H_2O Outlet Temperature °C (°F)	17.2	63	18.0	64.4

TABLE III

FINAL DESIGN DETAILS

3/ 5 10:35

INPUT DATA

6.300	LHOT	22.770	WH	1.	NPH		.425-15.	-.0050R	HOT FINS	
9.500	LCOLD	16.820	WC	4.	NPC		.050-18.	-.0050R	COLD FINS	
9.465	LNF	104.00	THIN	115.0	CM			.0100	PP	
.400	SF	43.50	TCIN	.100	DM			1.00	DPF	
.01000	AHIN	14.70	PB	.622	CL	3.65	CNU	3.65	HNU	

OUTPUT INFO.

.8913	EF	297.456	OS	56.795	OLAT	7.57	WT
.0147	SDPH	26.810	HAH	577.99	RNH	.0968	VDRY
.5944	SDPC	296.831	HAC	165.57	RNC	.2310	VWET
50.11	THOUT	64.56	TCOUT	19.	NH	20.	NC
.00766	AHOUT	76.57	TX	55.56	TY	57.30	TSIN
.2400	CPH	.0150	CFH	.0435	VFH	.075	DFH
1.0000	CPC	.3400	CFC	2.7000	VFC	62.400	DFC
8.89	HNUC	7.40	CNUC				

TABLE IIIA

INPUT DATA

L Hot	Hot Length, cm (in)
L Cold	Cold Length, cm (in)
LNF	No Flow Length, cm (in)
SF	Safety Factor
AHIN	Inlet Absolute Humidity - kg H_2O/kg dry gas (lb H_2O/lb dry gas)
WH	Hot Weight Flow - kg/sec (lb/min)
WC	Cold Weight Flow - kg/sec (lb/min)
THIN	Hot Inlet Temperature - °C (°F)
TCIN	Cold Inlet Temperature - °C (°F)
PB	Gas Inlet Pressure - kN/m^2
NPH	Number of Hot Passes
X1PC	Number of Cold Passes
CM	Metal Thermal Conductivity - watts/m °C (Btu/hr ft-°F)
DM	Metal Density - kg/m^3 (lb/in^3)
CL	$\frac{18}{\text{Gas Molecular Weight}}$
PP	Parting Plate Thickness - mm (in)
DPF	Correction Factor for Condensign Pressure Drop (= 1 for Dry Delta P)
HNU	Hot Side Nusselt Number
CNU	Cold Sid Nusselt Number
Hot Fins	Height-fin/cm-thick - cm, fm/cm, mm (in, f/in, in)
Cold Fins	Height-fin/cm-thick - cm, f/cm, mm (in, f/in, in)
EF	Effectivity - %

TABLE IIIA
(Continued)

SDPH	Hot Side Pressure Drop - kN/m^2 (psi)
SDPC	Cold Side Pressure Drop - kN/m^2 (psi)
THOUT	Hot Side Outlet Temperature - °C (°F)
AHOUT	Outlet Absolute Humidity - kg H_2O/kg dry gas (lbs H_2O/lbs dry gas)
CPH	Hot Fluid Specific Heat - Joules/kg °C (Btu/lb °F)
CPC	Hot Fluid Thermal Conductivity - watts/m^2 °C (Btu/hr ft °F)
HNUC	Calculated Hot Nusselt Number
QS	Sensible Heat - watts (Btu/min)
HAH	Hot Side Conductance - watts/°C (Btu/min°F)
HAC	Cold Side Conductance - watts/°C (Btu/min °F)
TCOUT	Cold Side Outlet Temperature - °C (°F)
TX	Hot Side Temperature at Pinch Point °C (°F)
CPH	Hot Side Thermal Conductivity - watts/m-°C (Btu/hr ft °F)
CFC	Cold Side Thermal Conductivity - watts/m-°C (Btu/hr ft °F)
CNUC	Calculated Cold Side Nusselt Number
Q LAT	Latent Heat - watts (Btu/min)
RNH	Hot Side Reynolds Number
RNC	Cold Side Reynolds Number
NH	Number of Hot Fin Layers
TY	Cold Side Temperature at Pinch Point °C (°F)
VFH	Hot Fluid Viscosity - N·sec/m^2 (lb/ft hr) abs. visc.
VFC	Cold Fluid Viscosity - N sec/m^2 (lb/ft hr)

TABLE IIIA
(Continued)

WT	Weight of Fins and Parting Sheets - kg (lbs)
VDRY	Dry Volume m^3 (ft^3)
VWET	Wet Volume m^3 (ft^3)
NC	Number of Cold Fin Layers
TSIN	Inlet Dew Point °C (°F)
DFH	Hot Fluid Densith kg/m^3 - (lbs/ft^3)
DFC	Cold Fluid Density kg/m^3 - (lbs/ft^3)

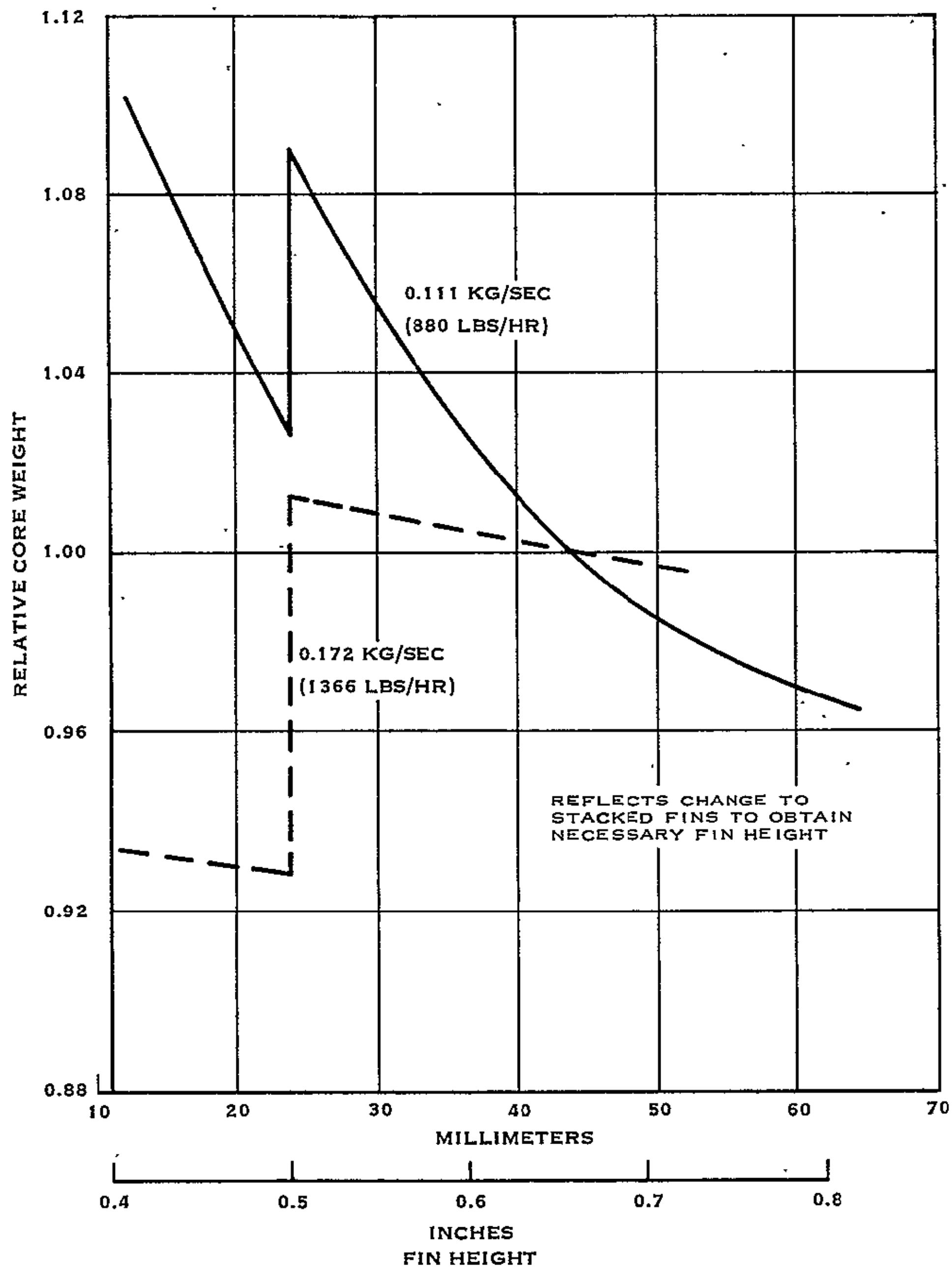


FIGURE 1. FIN HEIGHT EFFECT ON CORE WEIGHT

Design Layout

In addition to the thermal design discussed in the previous section, other design considerations were as follows:

Proof Pressure	
Water Side	618 kPa (75 psig)
Air Side	136 kPa (5 psig)
Leakage	No bubbles at proof pressure
Vibration	See Figure 2
Water Delta P	8.27 kPa (1.2 psi at 950 lb/hr)
Air Side Delta P	199 Pa (0.8 in H_2O at rated flow)
Weight	11.65 kg max (25.694 lbs max)

These requirements were achieved as shown below:

Proof Pressure - Minimum safety factor of 1.9.

Leakage - All welded or brazed construction - tested at proof pressure.

Vibration - Lowest safety factor is 1.5.

Water Delta P - Calculated to be 182.5 Pa (0.733 in H_2O) or a 64 percent margin.

Air Delta P - Calculated to be 149.7 Pa (0.601 in H_2O) or a 33 percent margin.

Weight - 11.12 kg (24.91 lbs) including five percent growth factor.

One major difference between the previous unit and the current design is the inclusion of slurpers on the latter. The slurper design requires that the air side fins extend from the face of the core over the slurper surface. This requirement, coupled with the thin water passes, virtually ruled out the possibility of weld repair of water passes without damage to the air fins. Therefore, a new manufacturing sequence was established which allowed the fabrication of the heat exchanger in four basic steps:

1. Brazing and weld repair of water modules
2. Core brazing without slurpers
3. Slurper fabrication
4. Final assembly including coating of core and slurpers, attachment of slurpers, headers, and mounting feet.

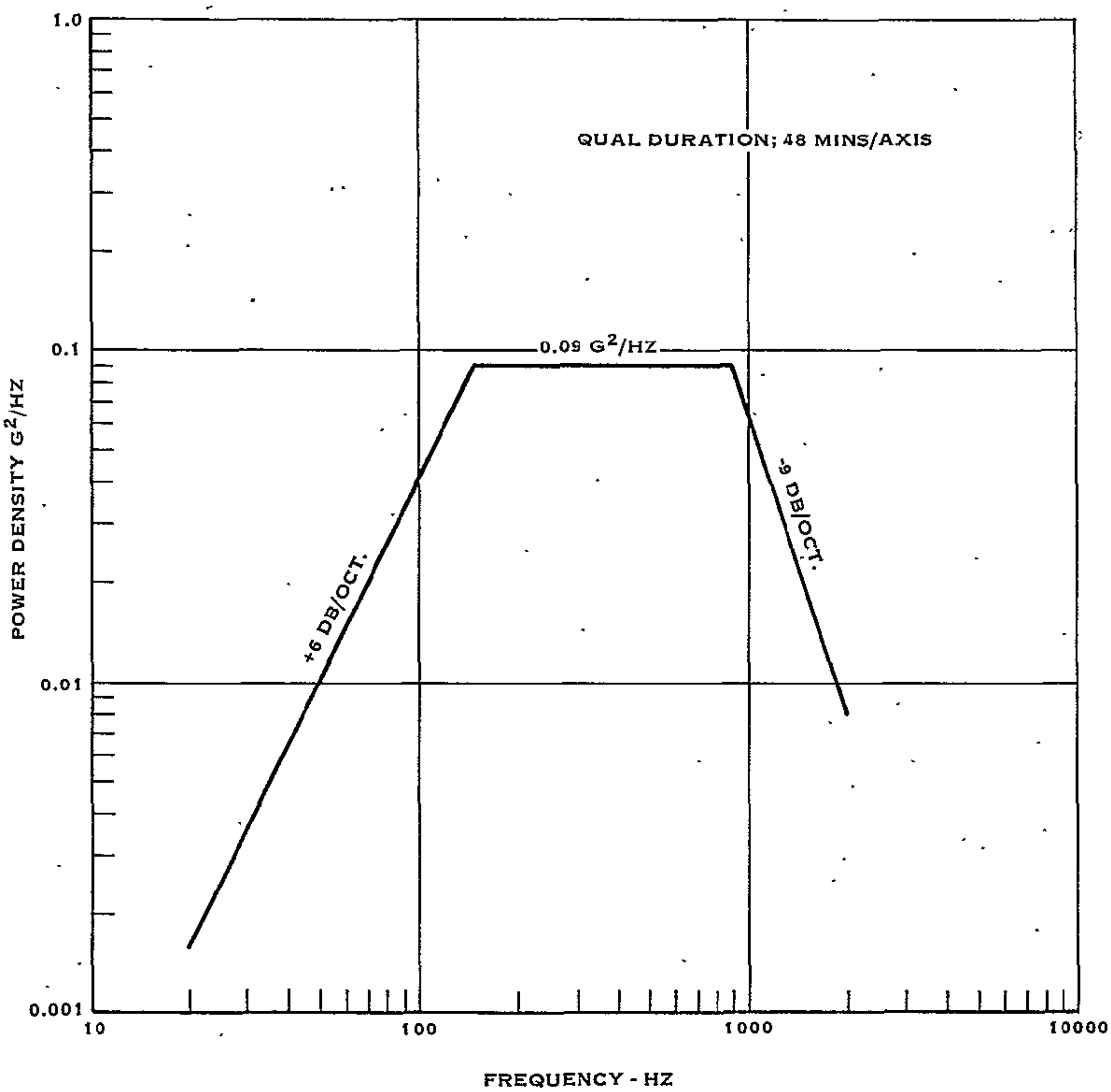


FIGURE 2. SHUTTLE ARS VIBRATION INPUT

Detail Drawings

Following completion of the layout, the final manufacturing drawings were made. Figure 3 shows the core drawing, while Figure 4 shows the heat exchanger drawing.

Quality Assurance

The design of the unit was such that known quality problems were eliminated. For example, the possibility of trapped brazing flux was avoided by the use of fluxless brazing. The possibility of poorly laminated parting sheets was reduced by the use of 100 percent ultrasonic inspection along with destructive sampling. In addition, the design of the unit was such that cleanliness of all parts could be attained and maintained throughout the assembly and braze process. The unit is capable of being cleaned, as an assembly, by the use of appropriate flushing procedures.

Reliability

As a completely brazed and welded unit with no moving parts, the only realistic failure mode is through corrosion of the parting sheets. The use of the laminated titanium sheets precludes this mode of failure. All other parts are tolerant of corrosion because of their thickness.

Safety

The unit was designed with safety margins which have been demonstrated during previous flight programs to provide adequate safety margins. The unit was tested at a proof pressure of 1.5 times the maximum normal operating pressure.

FABRICATION OF HEAT EXCHANGER

Because of the four step fabrication process planned for the heat exchanger, it was felt advisable to fabricate a feasibility core before committing the full scale parts, including the expensive composite parting sheets, to the four step sequence. Accordingly, this discussion of heat exchanger fabrication is divided into two parts; feasibility core fabrication and flight configuration fabrication.

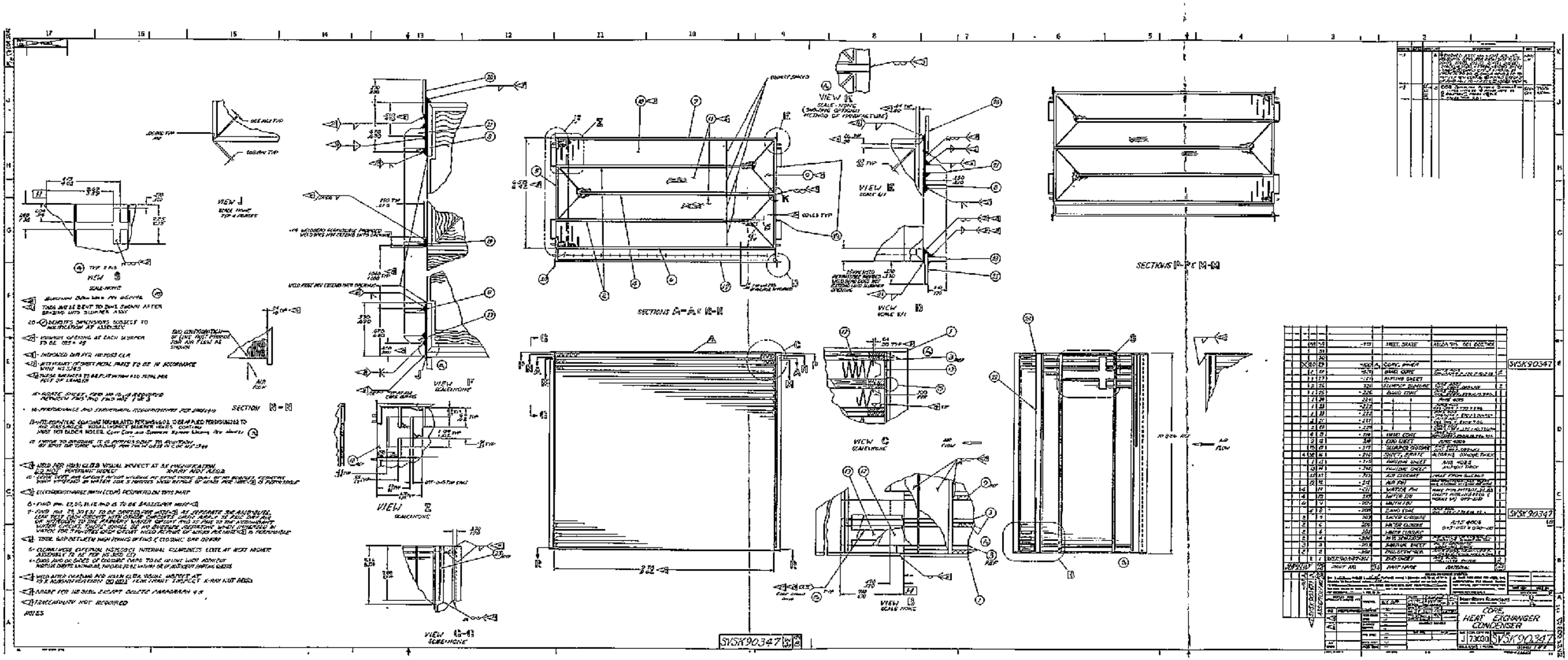


FIGURE 3 - CORE DRAWING, SVSK 90347

FOLDOUT FRAME 1

FOLDOUT FRAME 2

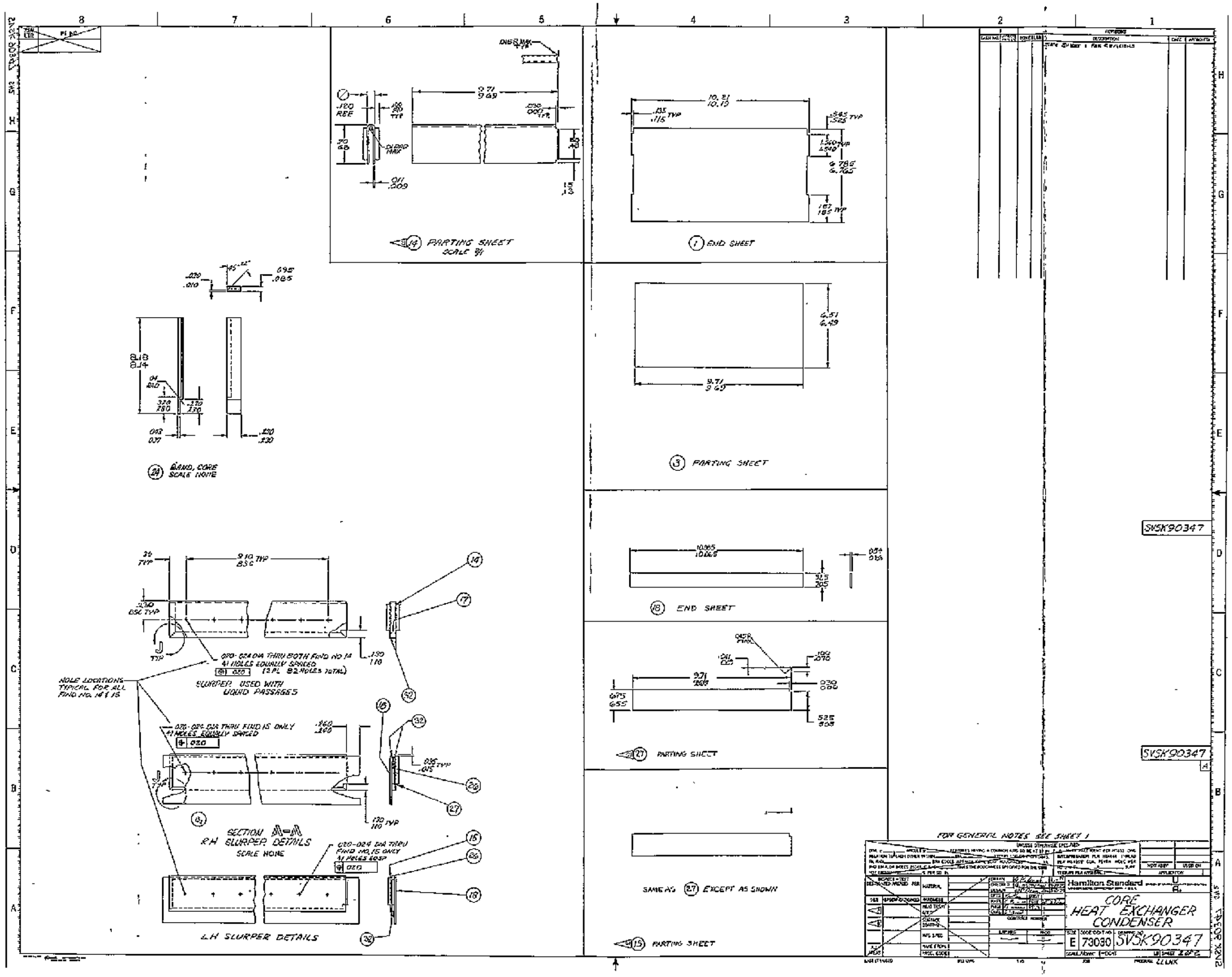


FIGURE 3 - CORE DRAWING, SVSK 90347 - CONCLUDED

FOLDOUT FRAME 1

FOLDOUT FRAME 2

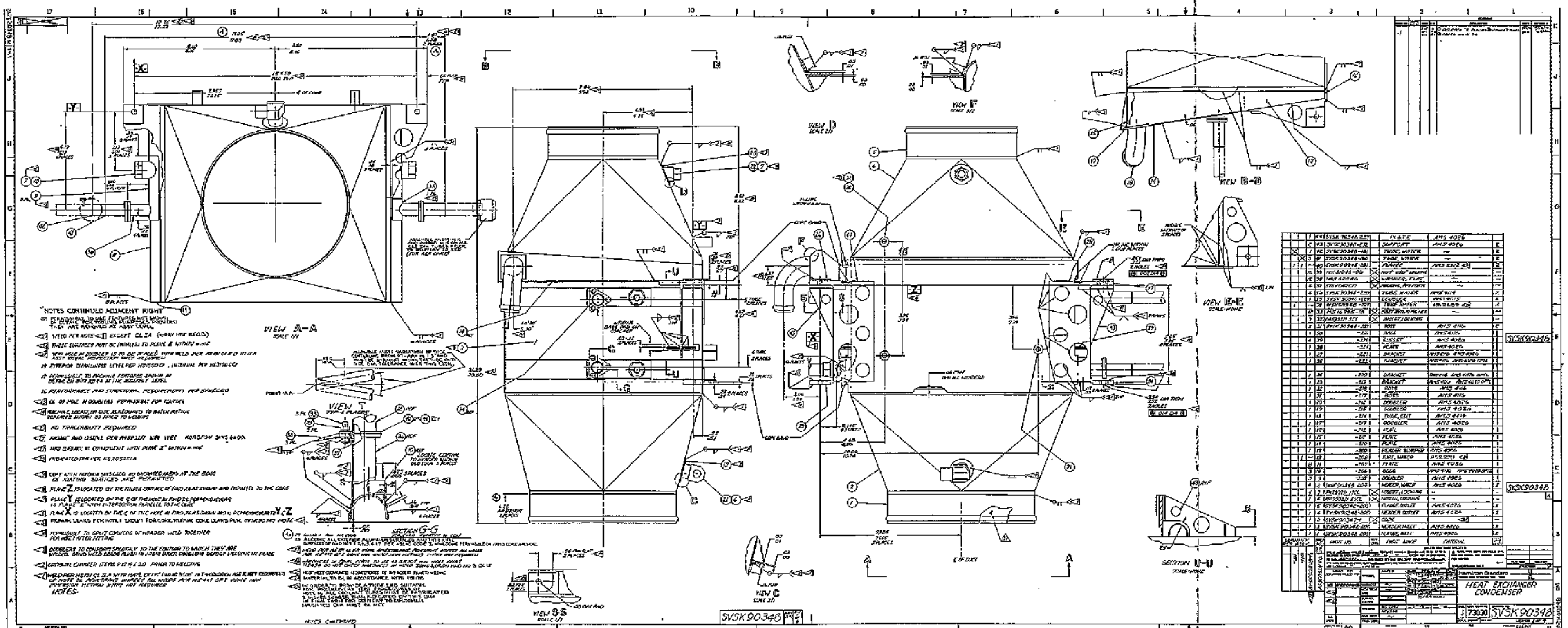


FIGURE 4 - HEAT EXCHANGER DRAWING, SVSK 90348

FOLDOUT FRAME 1

FOLDOUT FRAME

FOLDOUT FRAME 2

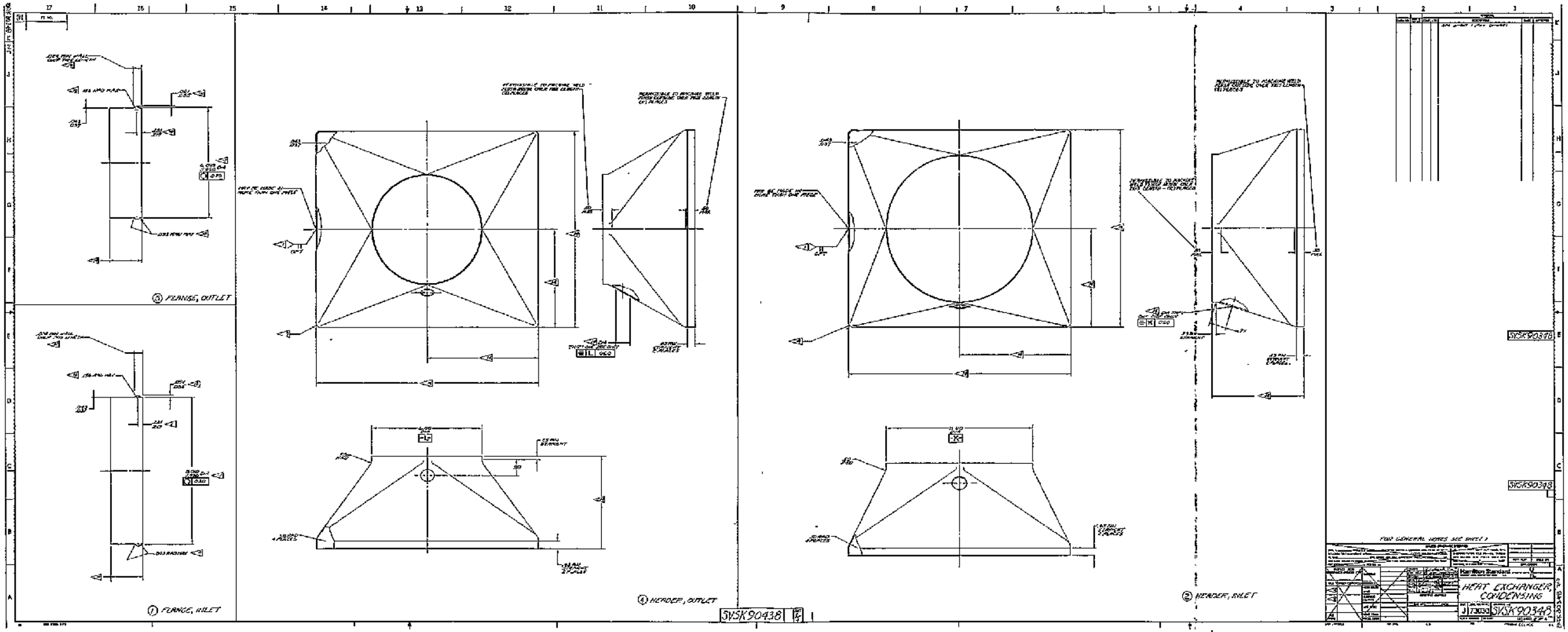


FIGURE 4 - HEAT EXCHANGER DRAWING, SVSK 90348 - CONTINUED

FOLDOUT FRAME 1

FOLDOUT FRAME 2

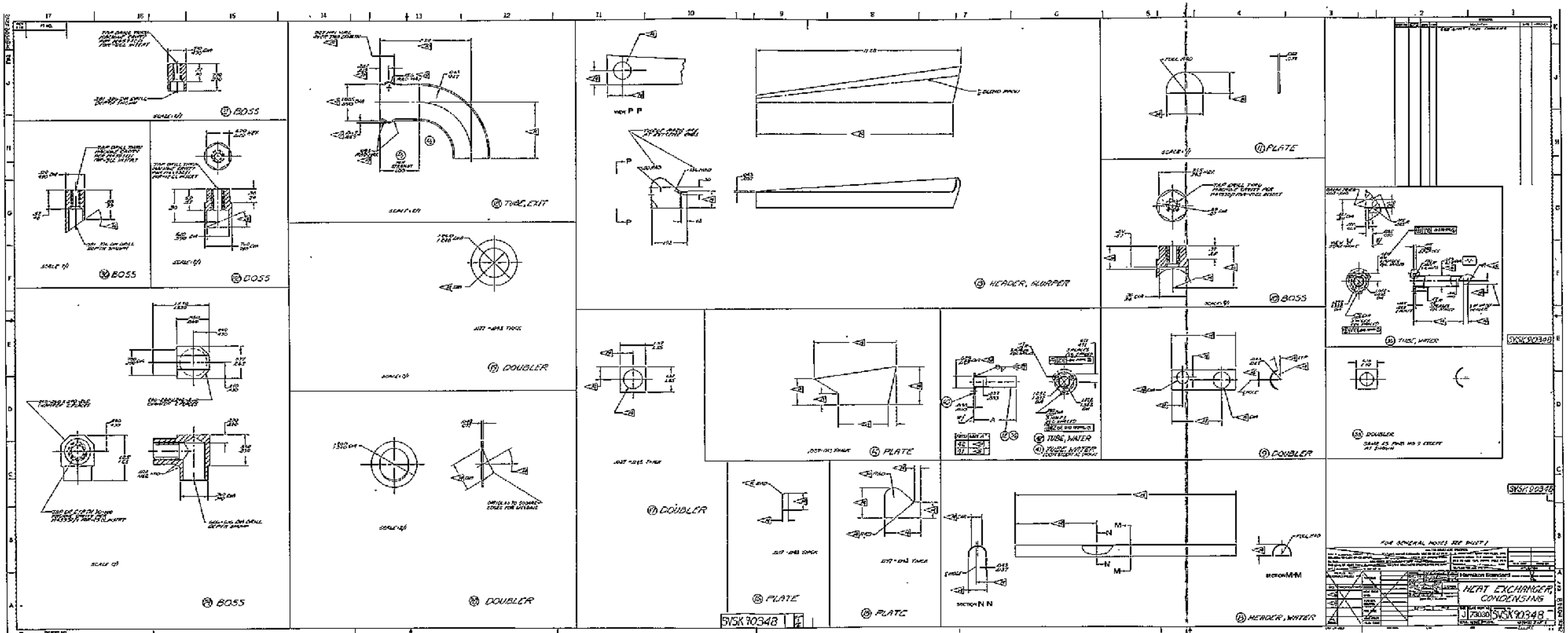


FIGURE 4 - HEAT EXCHANGER DRAWING, SVSK 90348 - CONTINUED

FOLDOUT FRAME 1

FOLDOUT FRAME 2

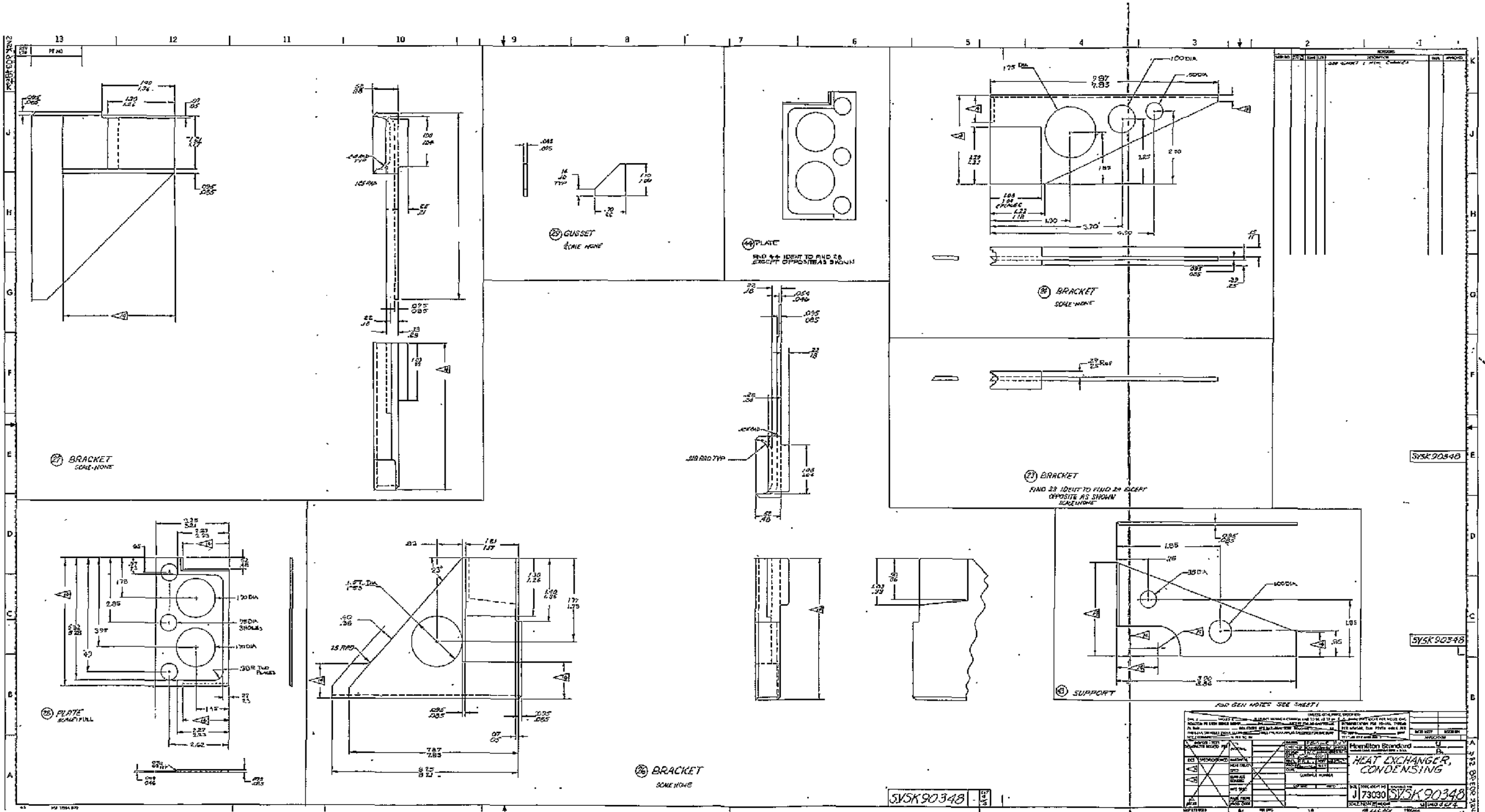


FIGURE 4 - HEAT EXCHANGER DRAWING, SVSK 90348 - CONCLUDED

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Feasibility Core Fabrication

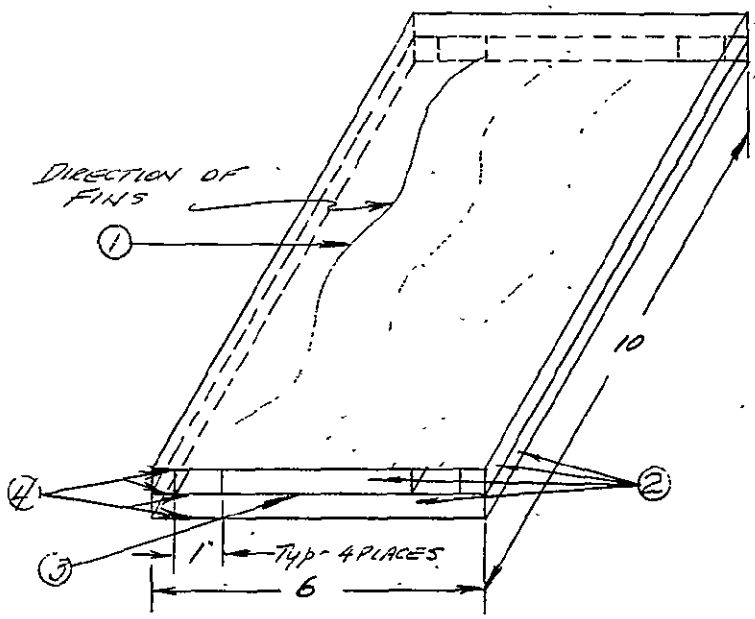
A feasibility core was designed using the same materials as the flight configuration but not intended to be operational; i.e., no headers, hydrophilic coating, or mounting provisions. The design used parting sheets the approximate size of the full scale core, 15.24 cm x 25.4 cm (6 in. x 10 in.), but contained only four water modules rather than the twenty utilized by the full size heat exchanger. See Figures 5 through 8. Fin sizes and closure bar sizes were the same as the full size unit. Two of the four modules made used AMS 4025 closure bar material for evaluation purposes, while the other two used AMS 4006, the material called out for the full scale core. Leakage tests of the modules showed the AMS 4006 to be significantly better than AMS 4025.

Brazing the modules into a core initially produced poor results. The third attempt resulted in acceptable brazes. The first feasibility core, Figures 9 and 10, contained excellent water and air fin to parting sheet brazes, good AMS 4006 closure bar brazes, poor AMS 4025 brazes, and poor air closure bar to parting sheet brazes. Figure 11 shows typical air fin and water fin to parting sheet brazes, Figure 12 compares the AMS 4025, and AMS 4006 results, and Figure 13 the air closure bar brazes.

Extensive metallurigical analyses including microphotographs, scanning electron microscope, x-ray analysis, and microprobe analysis were utilized in an effort to find the cause of the poor braze found in the first two feasibility cores. The results, while not conclusive, suggested two possible modes, operating singly or together, which could have caused the inadequate braze. The results showed no contaminants which would have caused poor braze, but a higher than normal magnesium content (approximately 1% versus a normal 0.6%) was noted in fins adjacent to the closure bars. Also noted was that although excellent wetting of both fins and laminate was achieved (See Figure 14), little braze material remained at the closure bar-laminate interface. This suggests that the excellent wetting of both closure bar and laminate surfaces caused by the high magnesium concentration present also resulted in excessive flow of the braze material across adjacent surfaces instead of remaining in the joint through capillary action. This excessive flow or wetting appears to be confirmed by the surface flow of braze material on fins adjacent to the closure bar. Figure 15 shows the extent to which braze alloy flowed both from the top downward and the bottom upward as well as "modules" of braze material.

E Lan
2/25/75

REV A 5/14/75



(A)
No REQUIRED 4 REDUNDANT LAYER MODULES, INNER

MATLS 1) FINS- .050 high x 15 per inch x .005 thick, Ruffled.
2 REQ'D/MOD 5.8 WIDE x 9.8 long MAT'L- HS 3906
2) CLOSURE BARS- .050 high x .100 wide
4 REQ'D/MOD- 10 in. long
2 REQD/MOD 3.8" Mat'l- AMS 4006
2 REQD/MOD- 5.8
3) PARTING SHEETS 6" x 10" x .012 (.014 optional)
3 REQ'D/MOD MAT'L- AA3003
4), BRAZE SHEETS - 6 x 10 x .002 (.0015 opt)
4 REQ'D/MOD ALCOA 718 (713)
(A) MAKE 2 USING ALCOA 718 AND 2 USING ALCOA 713
(A) MODULE

FIGURE 5
CORE SECTION

Elan
2/25/75
REV 5/14/75

NO REQ'D 1 (ONE) ASSEMBLY

MAT'LS · ① 4 WATER MODULES

② AIR FINS .425 high x 15 per inch x .005 thick, ruffled
3 REQ'D 6.150" LONG x 9.688 WIDE MAT'L HS 3906

③ Closure bars .426 x .156. P/N 565967 6.84" Long.
6 REQ'D AMS 4006 (AA 3003 REF)

④ Braze sheet 6 x 10
alcoa. 718
6 REQ'D

⑤ END SHEETS
AMS 4006, .046-.054
Thick. 2 required.

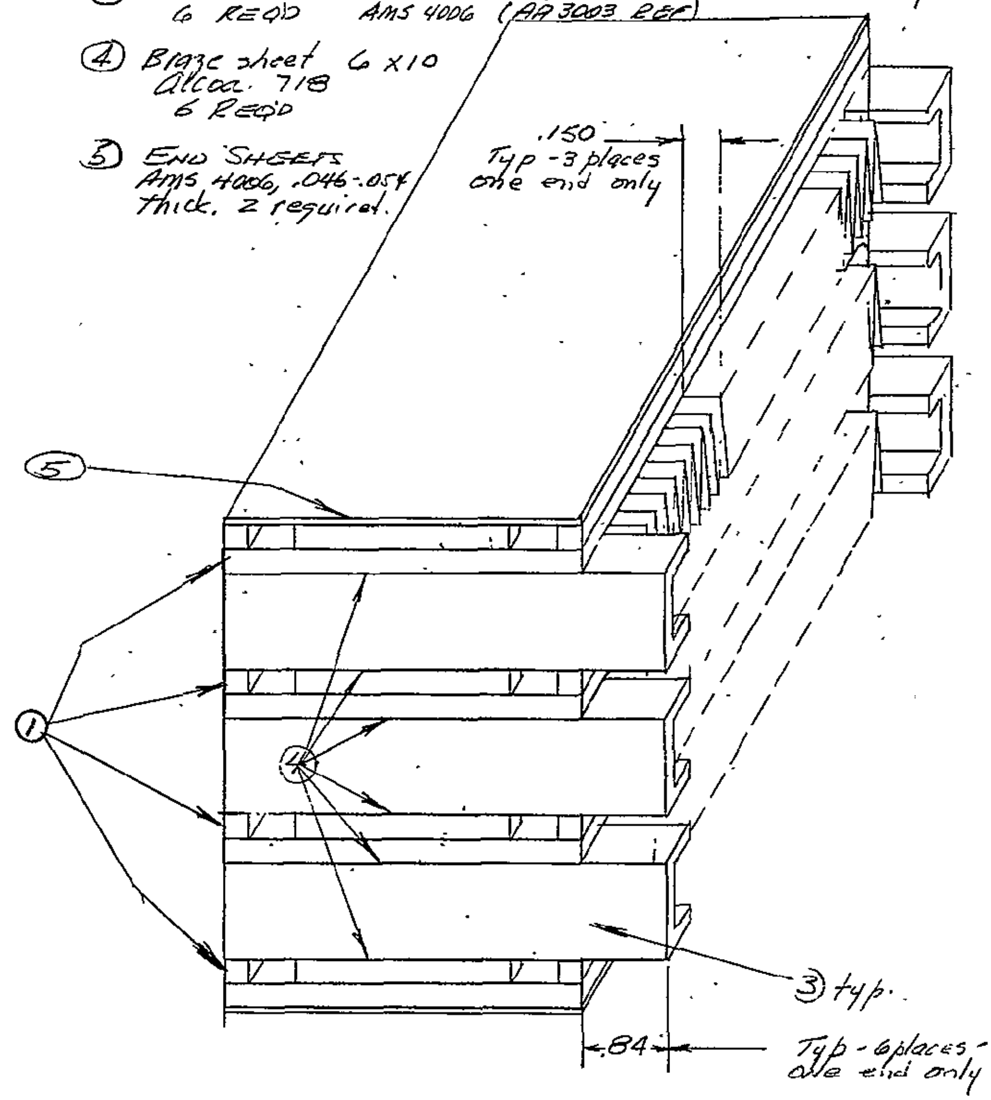
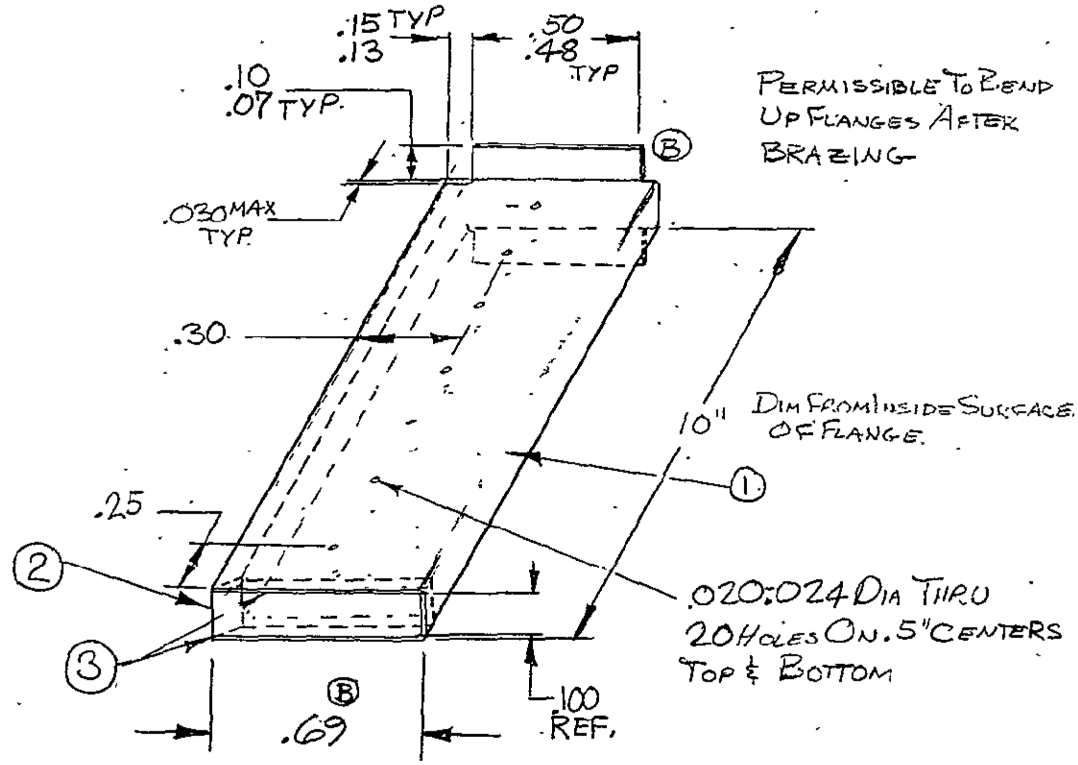


FIGURE 6 FEASIBILITY TEST CORE

Rev A 3-11-75 WGD
Rev B 4-3-75 WD

SLURPER MODULE



No Reqd - 2 Slurper Modules

Materials
(1) Cover - .010, .012, or .014 Aluminum AA 3003

(A) (2) Closure Bar - .080/.070 x .101/.099 AA 6061

(3) Braze Foil - Alcoa 718 As Reqd

(B) Unless Otherwise Specified Use ±.030 On All Dims

SLURPER MODULE

FIGURE 7

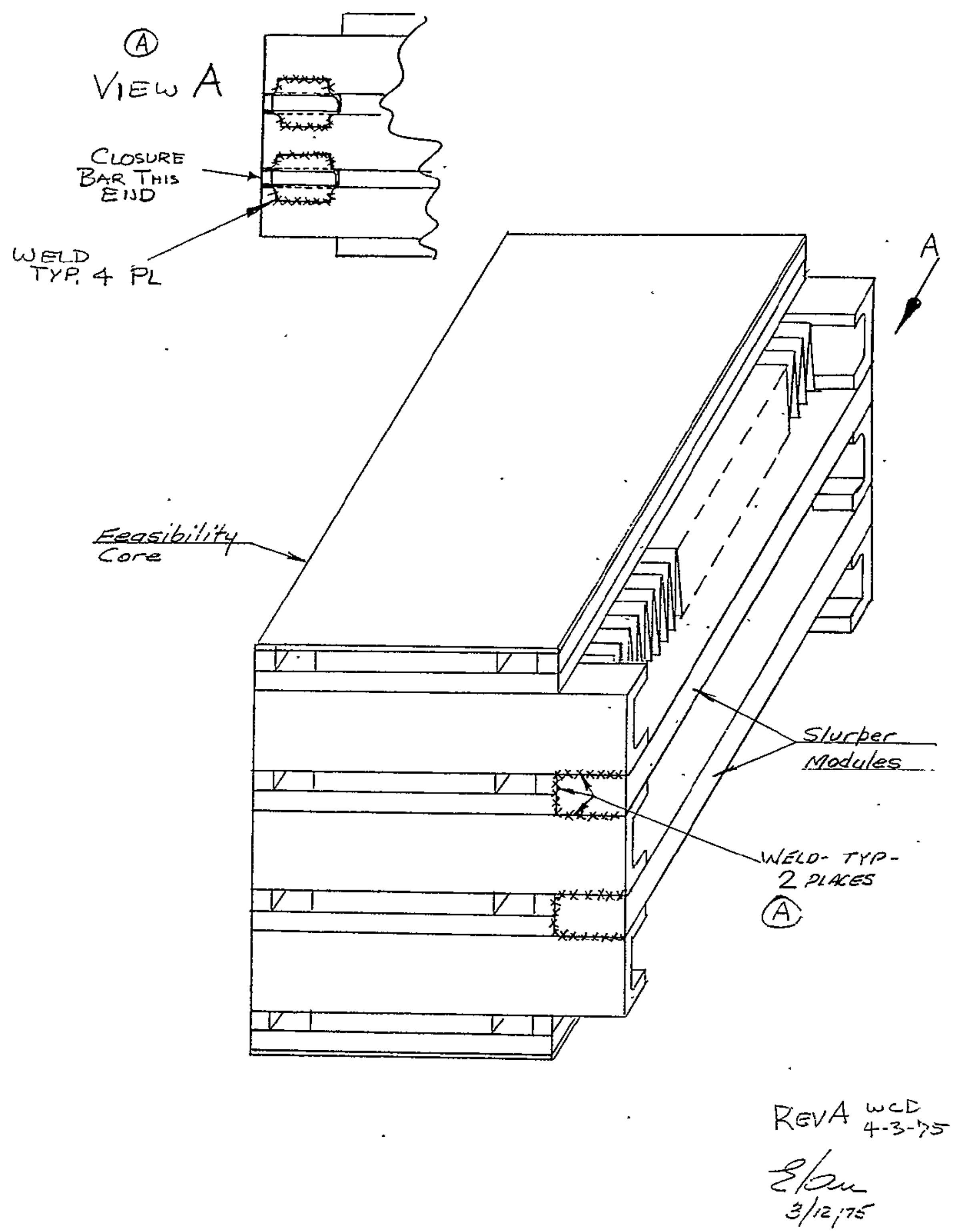
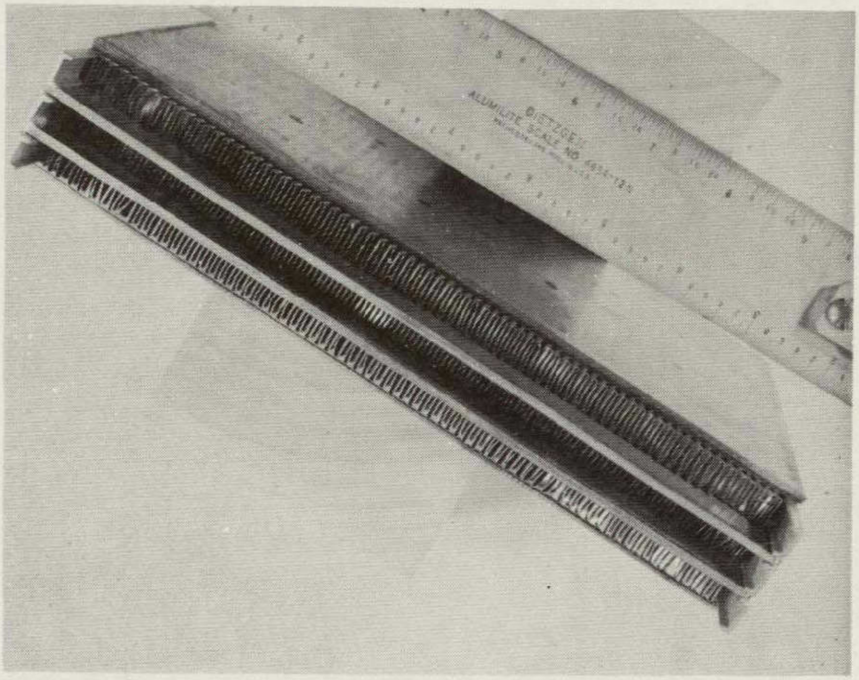
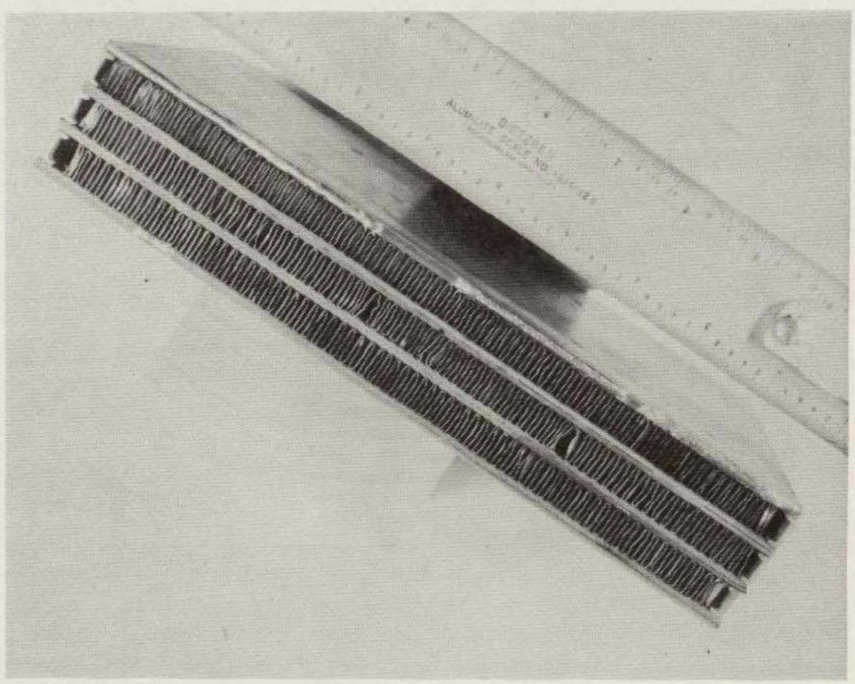


FIGURE 8
FEASIBILITY TEST CORE WITH SLURPER MODULES

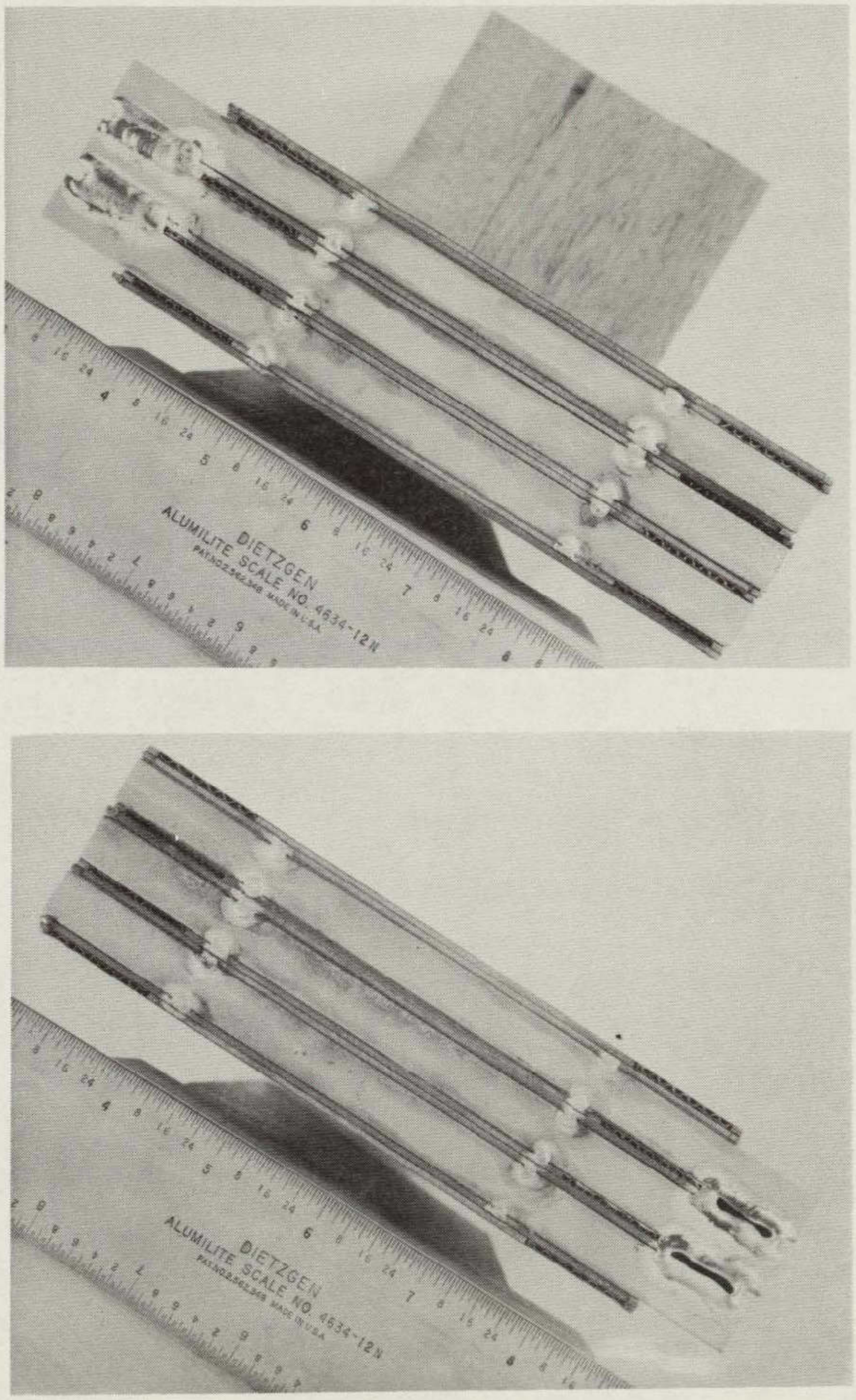


AIR OUTLET END WITH SLURPERS



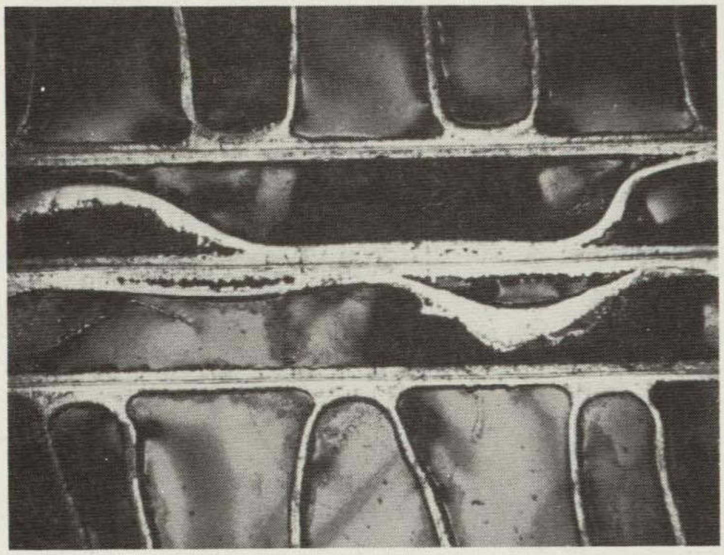
AIR INLET END

FIGURE 9

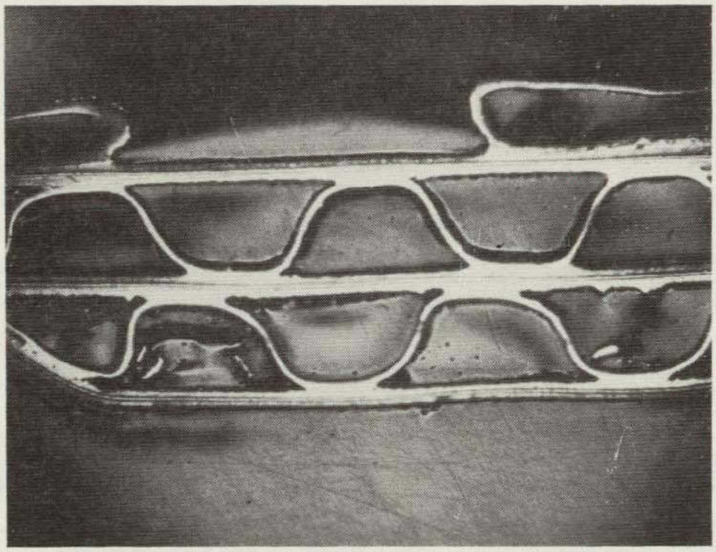


MODULE SIDE VIEW

FIGURE 10



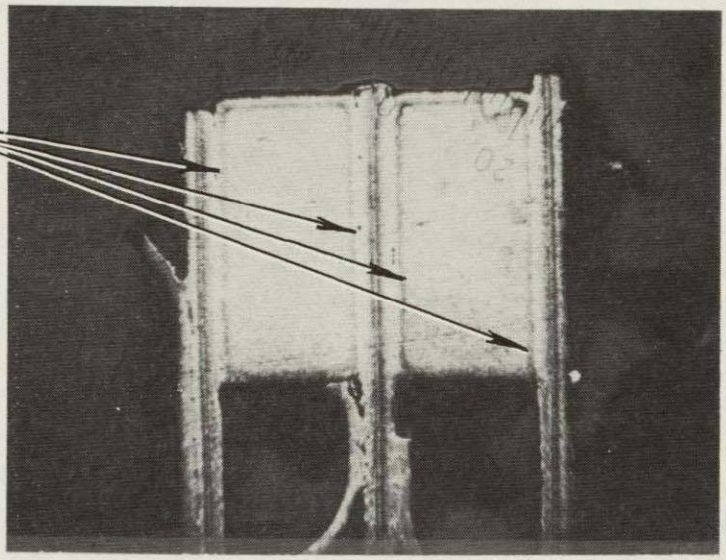
TYPICAL AIR FIN BRAZE



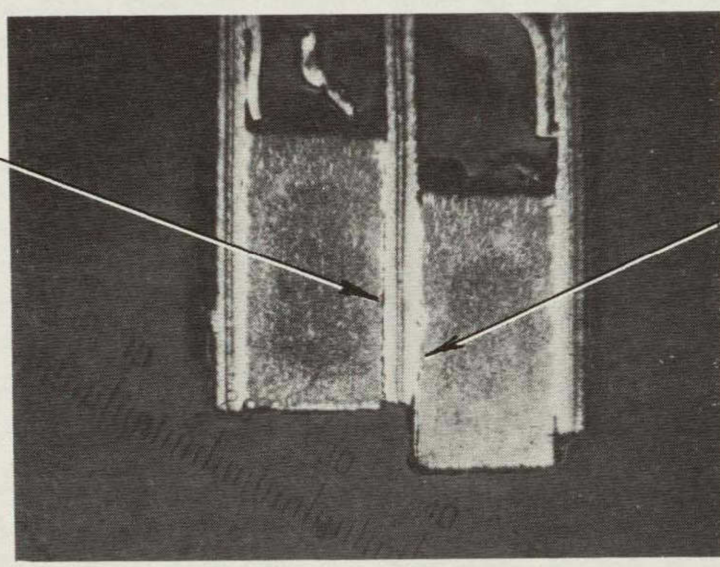
TYPICAL WATER FIN BRAZE

FEASIBILITY CORE NO. 1

FIGURE 11



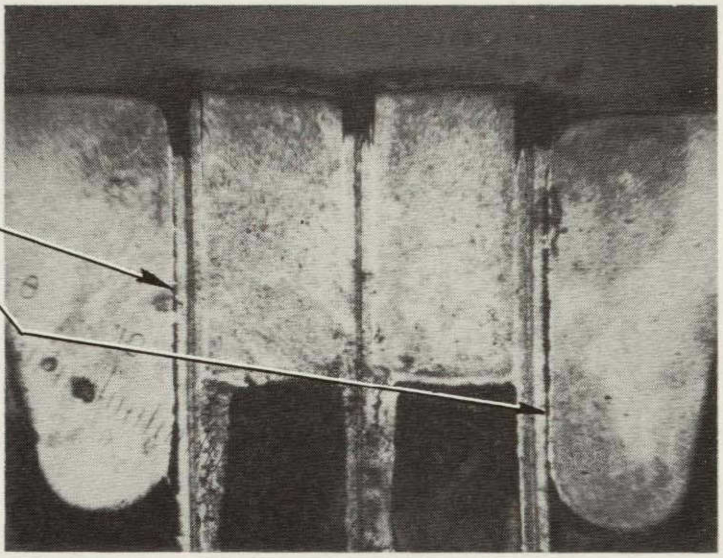
AMS 4006 CLOSURE BARS



AMS 4025 CLOSURE BARS

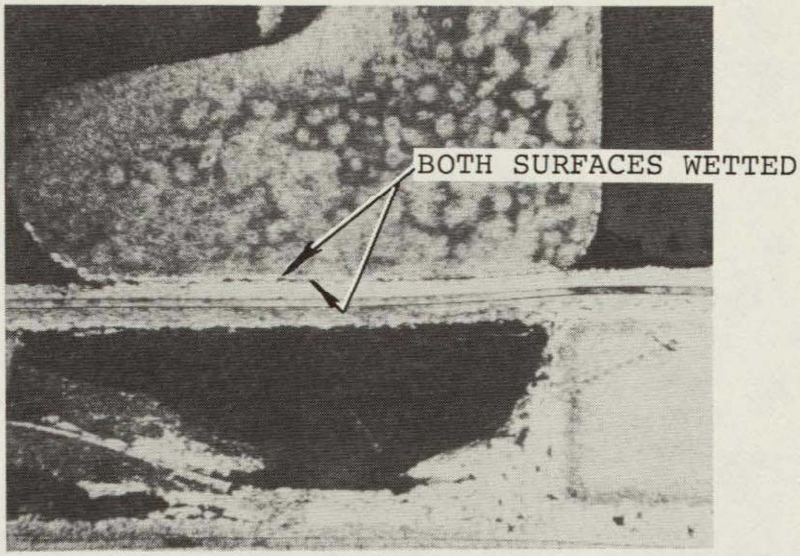
FIGURE 12

NO PARTING
SHEET WETTING



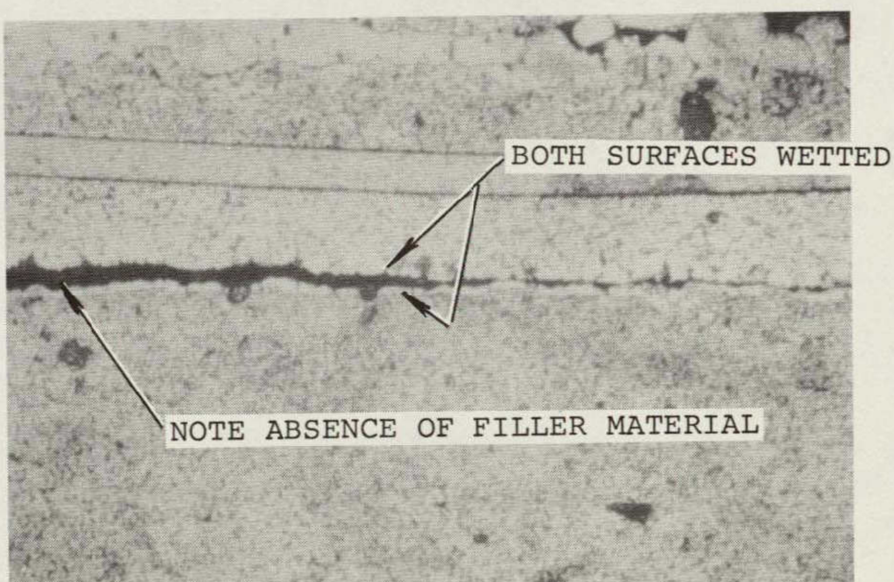
AIR CLOSURE BARS

FIGURE 13



20X MAGNIFICATION

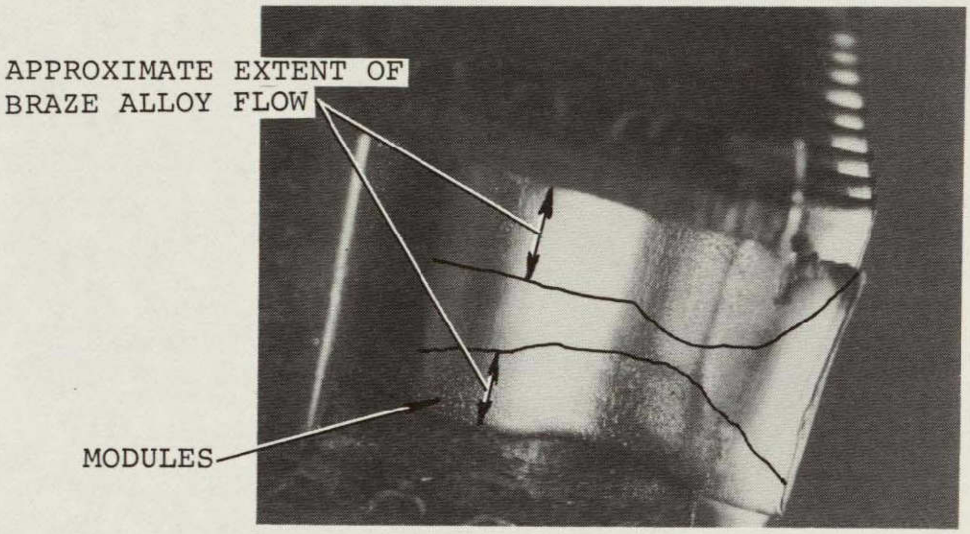
SURFACE WETTING



100X MAGNIFICATION

FILLER MATERIAL

FIGURE 14 SECOND FEASIBILITY CORE



4X MAGNIFICATION

BRAZE ALLOY FLOW

FIGURE 15 SECOND FEASIBILITY CORE

The results also showed the presence of a probable aluminum oxide film separating both wetted surfaces (see Figure 16). It is believed that a heavy aluminum or magnesium oxide was present on the water modules as a result of their braze cycle, and this oxide was broken up during the braze but was penetrated by the braze alloy to allow wetting beneath the oxide. Since the alloy will not braze to the oxide, the intervening oxide precluded a satisfactory braze.

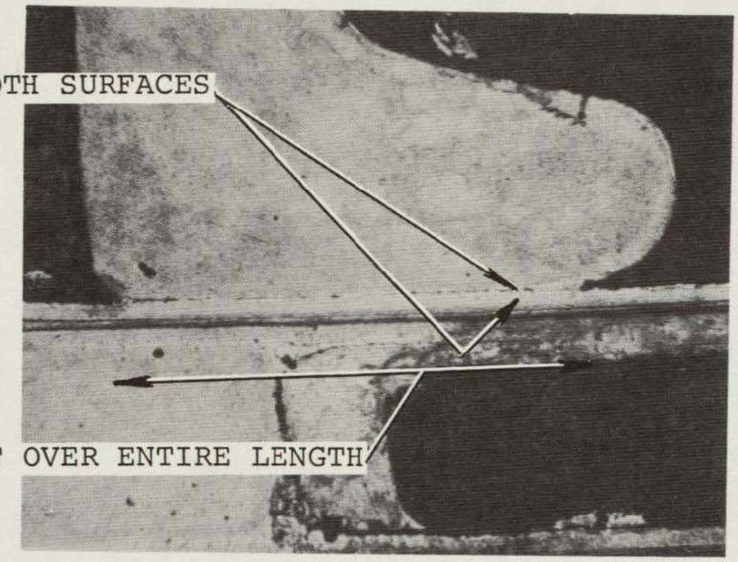
The modules surface had been lightly abraded in the area of the closure bars prior to brazing to remove the magnesium hydroxide suspected to have caused the lack of wetting in the first core. The amount of abrading used apparently was sufficient to remove the hydroxide and allow wetting but not sufficient to remove the oxide.

The third and successful feasibility core was brazed with two changes; the braze alloy was changed to Alcoa 713 (a higher melting alloy) and heavier abrasion at parting sheet edges using "Beartex", a material known from previous experience, not to leave contamination on the abraded surface. Metallurigcal examination indicated "typical" fluxless brazes similar to the AMS 4006 braze of Figure 12.

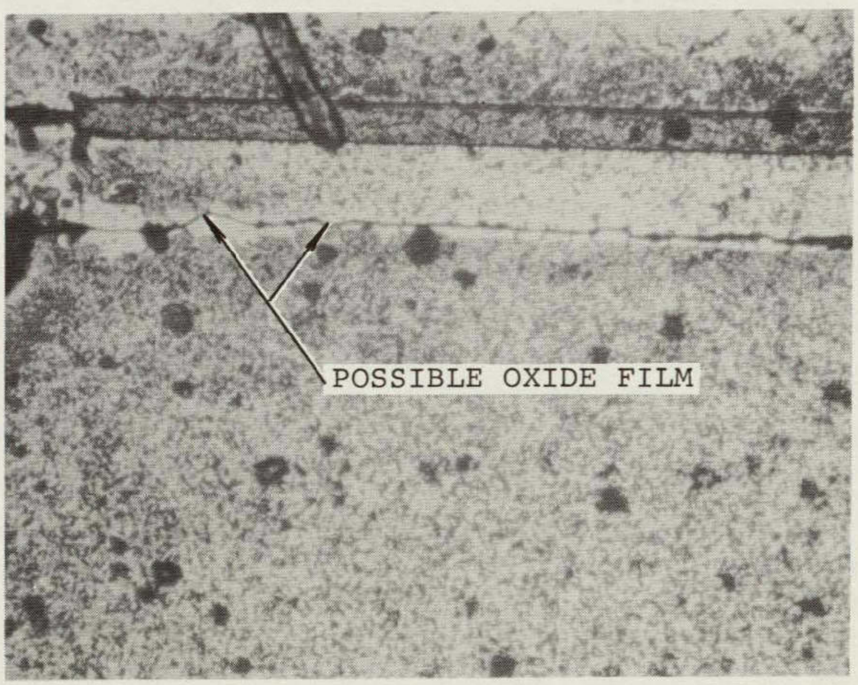
Heat Exchanger Fabrication

After the fabrication of parting sheets, the manufacture of details and the successful feasibility core, the first of two sets of 20 modules was brazed. The first set produced several modules with "collapsed" faces between the pass separators. (See Figure 17.) Destructive examination of the worst of the modules revealed partial melting of the fins in local areas, see Figure 18; and the melting allowed "collapse" of the faces. The local melting was caused by migration of silicon from the braze alloy to the grain boundaries of the fin, lowering the melting point at the grain boundaries, see Figure 19. The migration occurs because the braze alloy has a nominal seven percent silicon, while the fin material has a nominal 0.6 percent.

Although local melting occurred, strength is relatively unaffected because in most cases material is not displaced and solidifies in its original position as in Figure 19. Before the module was destructively examined, it was leak tested using pressures to 50 psig with no apparent distortion or failure.



20X MAGNIFICATION



100X MAGNIFICATION

FIGURE 16 SECOND FEASIBILITY CORE

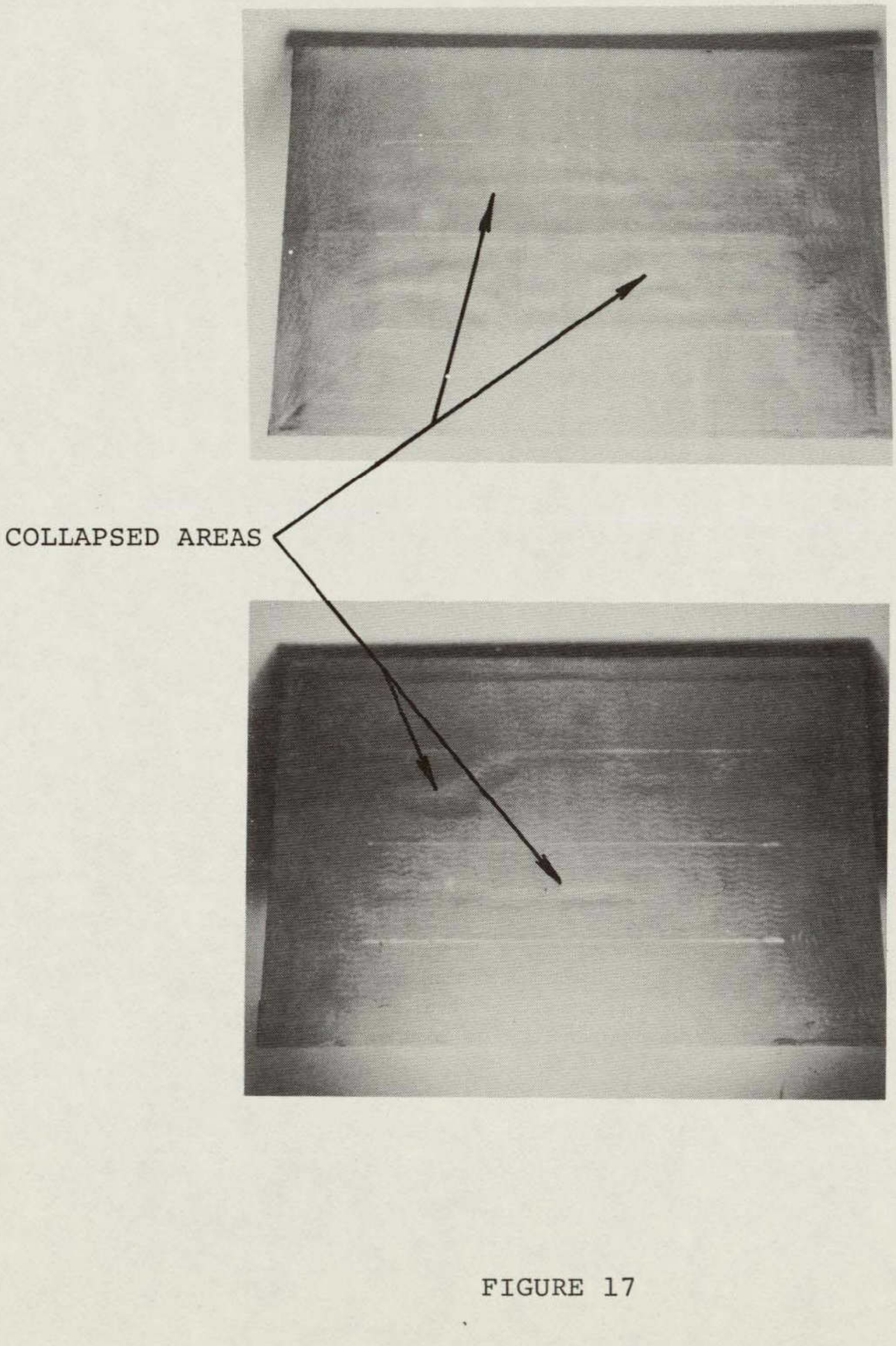
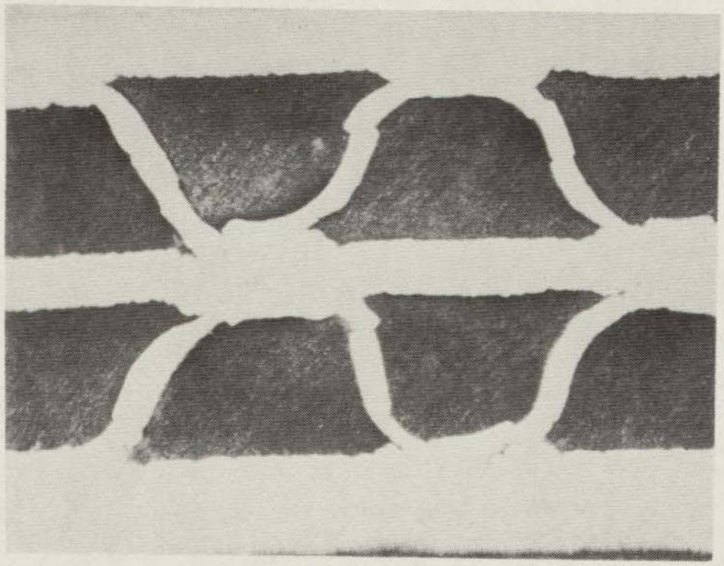


FIGURE 17



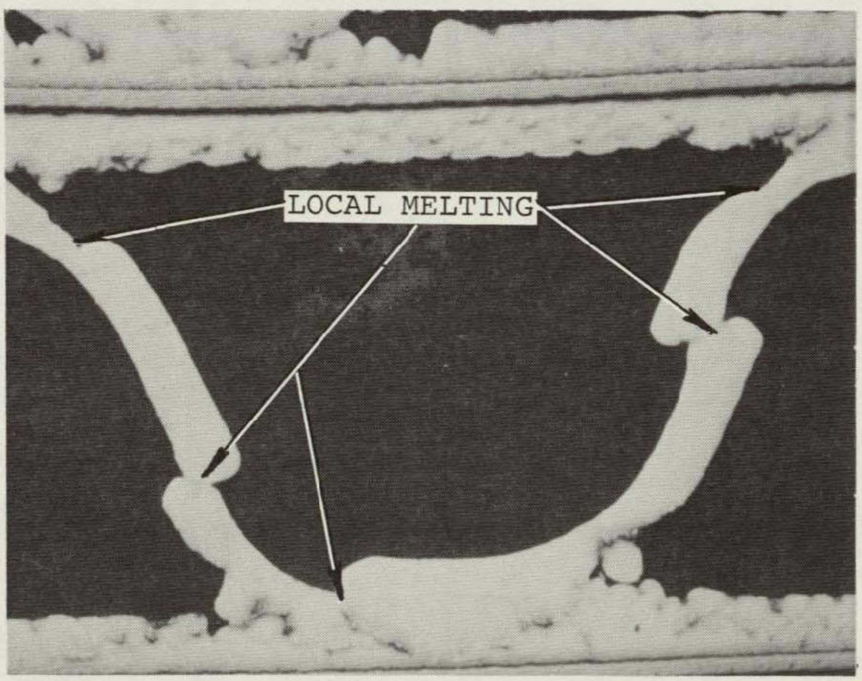


FIGURE 18

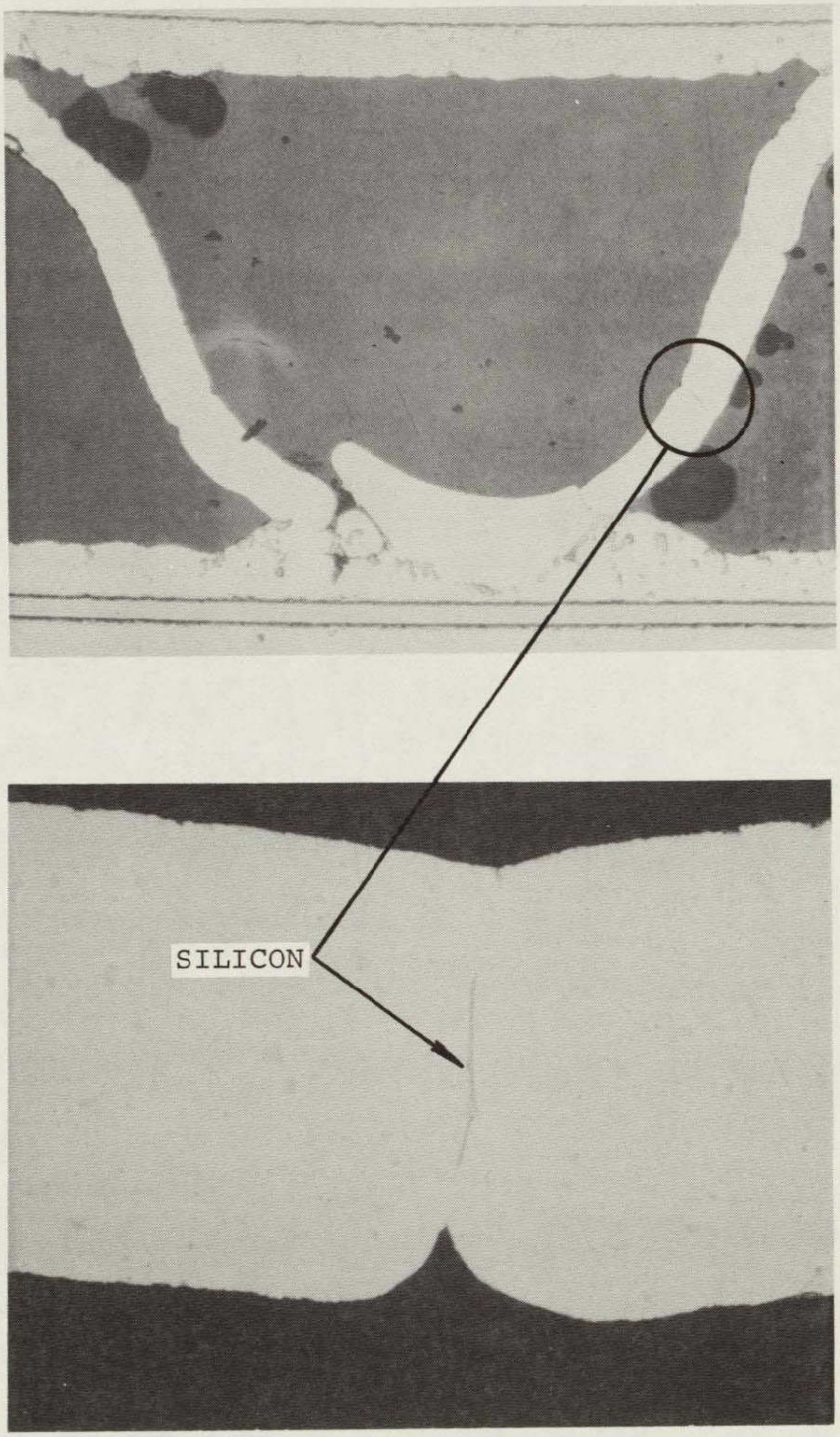


FIGURE 19

To prevent recurrence in the second lot of modules, several steps were taken. The furnance was recalibrated for temperature, new calibrated thermocuples were used, and the braze temperature was lowered to 1,130°F maximum; the first lot had used 1,140°F maximum with 1,135°F being attained with some scatter in the four thermocouples. The actual temperature attained with the second lot was 1,130°F with identical readings from all four thermocouples six minutes after furnace power was turned off. Visual examination of the mdoules showed no evidence of the local "collapse condition."

All of the modules showed excellent leak test results with leaks occurring only where expected; at the end of the center pass separator and at the water entrance and exist areas.

Twenty water modules, which had all passed leakage test, were stacked with air closure bars and fins, tack welded and brazed. Brazing was accomplished at 1,135°F with a one psi top load with mechanical stops to prevent collapse. The resulting core looked good with evidence of slight collapse at one air closure bar. A slight, unexplained sideways shift of the top three passes occurred but did not affect the heat exchanger assembly.

Leak testing and weld repair of the core followed the brazing operation. In all, approximately 20 external leaks in water modules were found. In addition, one internal leak from a secondary water pass to an air pass was found. All external leaks were successfully repaired prior to the addition of core bands, headers, and mounting brackets.

After welding of external leaks, the water core bands and headers were welded in place, mounting brackets fitted and welded, and slurpers and air headers were fitted following which the slurpers and partially completed heat exchanger had hydrophilic coating applied. The coating covered the outer surfaces of the slurpers and all the air passages in the core. Following coating, the slurpers were welded in place, using a "diffused" electron beam technique. The addition of slurper core bands, header, and end plates and air headers completed the heat exchanger. Following leak test, all openings were masked and final machining accomplished. All internal surfaces were alodined, the heat exchanger inspected, and then delivered to the test area for various tests. The final process inspection of the unit noted above had indicated a leak between the primary and secondary water circuits as a result of slurper header and/or air header welding. A leakage test at that time had shown the leak to be approximately 12 cc/min based on a calculated volume of 950 cc. Since the specific location of the leak could only be determined by destructive examination by removal of headers and the risk of losing the heat exchanger through this procedure was assessed as too great, it was decided to proceed with completion of fabrication and testing.

TEST OF HEAT EXCHANGER

Test Plan

A test plan was prepared and approved which was intended to demonstrate both the performance and environmental capabilities of the heat exchanger. The tests included were:

1. Weight
2. Visual Examination
3. Coating Wettability
4. Proof and Leakage
5. Performance
6. Proof and Leakage
7. Vibration
8. Proof and Leakage
9. Performance
10. Coating Wettability
11. Weight
12. Post Test Visual Examination

Late in the program when it was apparent that the difficulties in manufacturing the heat exchanger, i.e., the recycling of the feasibility module and the dual cycle to obtain satisfactory modules, had reduced resources intended for testing, the test program was shorted to exclude the environmental and associated tests on the basis that the intended use for this heat exhanger did not include a need for demonstrated structural capabilities.

The tests performed were:

1. Weight
2. Visual Examination
3. Coating Wettability
4. Proof and Leakage
5. Performance
6. Proof and Leakage
7. Coating Wettability
8. Weight
9. Post Test Visual Examination

The test plan, in its entirety, is included as Appendix A.

Tests

Each of the tests performed is discussed below, and log sheets for the tests may be found in Appendix B.

Weight

The heat exchanger was subjected to two vacuum drying cycles and weighed after each cycle with weights of 8.736 and 8.731 kg (19.26 and 19.25 lbs) recorded. The requirement was 9.434 kg (20.8 lbs) which is 60% of the weight of the equivalent stainless steel heat exchanger of 15.724 kg (34.67 lbs). The 8.7335 kg (19.255 lb) weight of the heat exchanger represents 55.5% of the equivalent stainless steel heat exchanger.

Note: Because a temperature controlled vacuum oven was available at the time the unit was weighed, the drying cycle used was two hours minimum at 14 mmHg maximum and 37.7°C (100°F) minimum instead of the conditions called out in the test plan.

Visual Examination

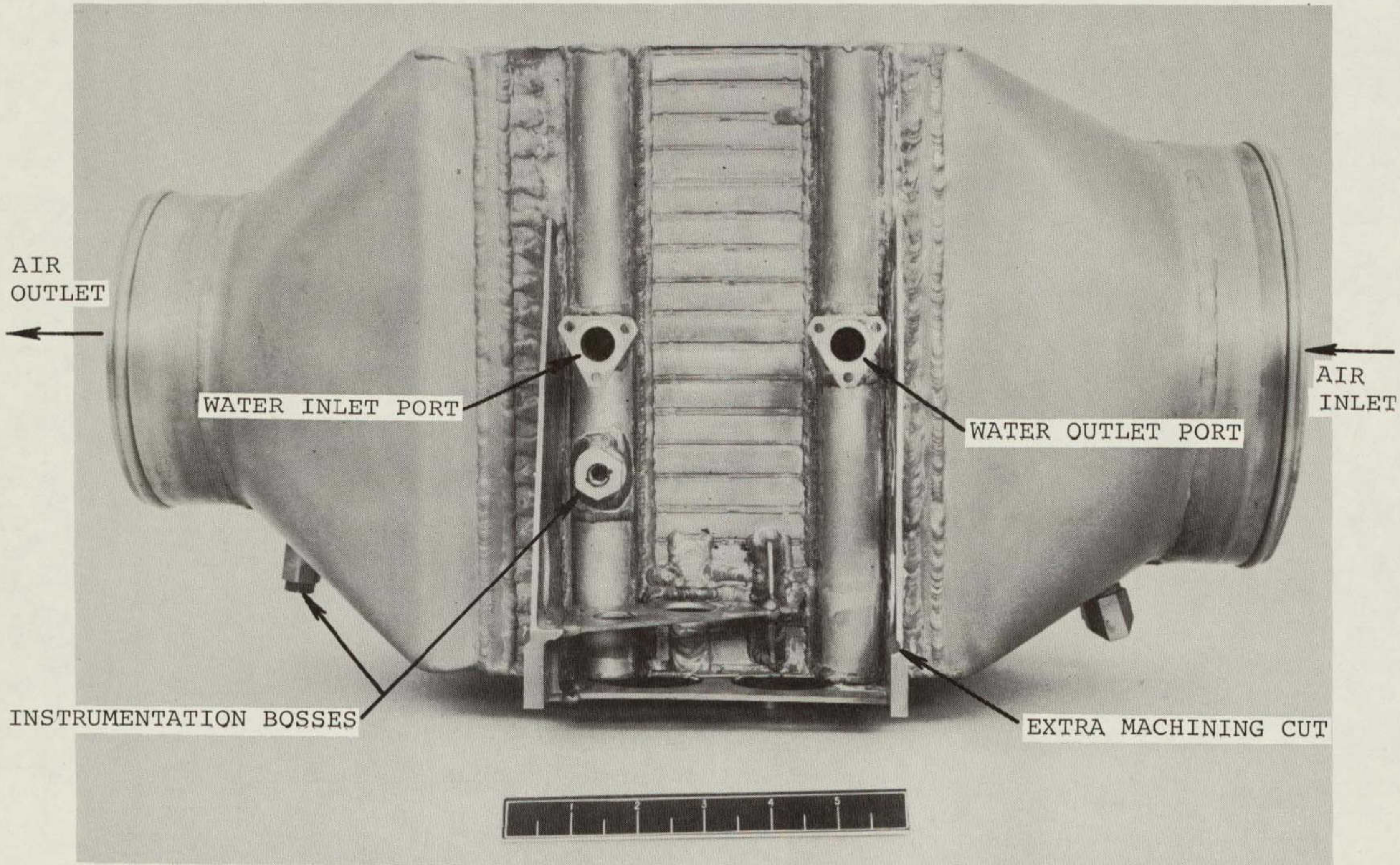
Inspection showed a machining error (undercut) at one of the mounting bosses, but since no structural testing will be performed on this unit, no corrective action was taken. See Figure 20.

Figures 20 through 27 depict all sides of the heat exchanger after test. Before test views are not shown because there are no discernible differences. Figure 23 shows a dent, from unknown causes, that has no effect on performance or leakage that was present when testing began.

Coating Wettability

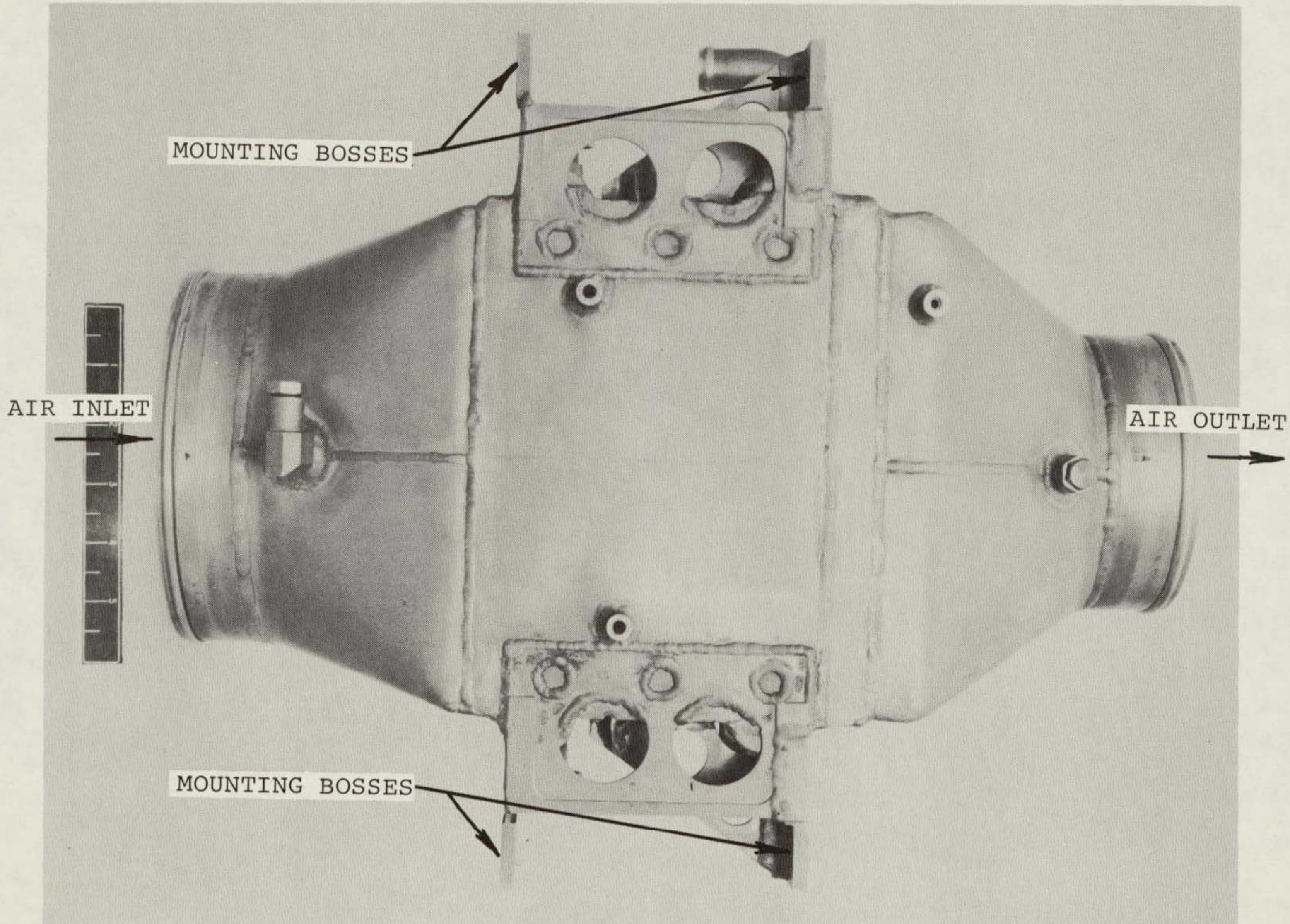
Per the plan of test, the slurper coating was sampled in twelve places. The "contact angle" and "time to wet" requirements were met in six places and were not met in the remaining six places, although immediately after the coating had been applied a spot test in one location checked out satisfactorily. The most likely cause for the change in characteristics is contamination from some source, probably not identifiable. A possible cause could have been a burned thermocouple lead during curing of the hydrophilic coating. A low temperature lead had inadventently been used to monitor oven temperature. At the 500°F part of the cure cycle, this lead burned giving off fumes which may have affected the thinner parts of the coating.

Since the effect of a partially contaminated slurper coating was not known, it was decided to continue testing.



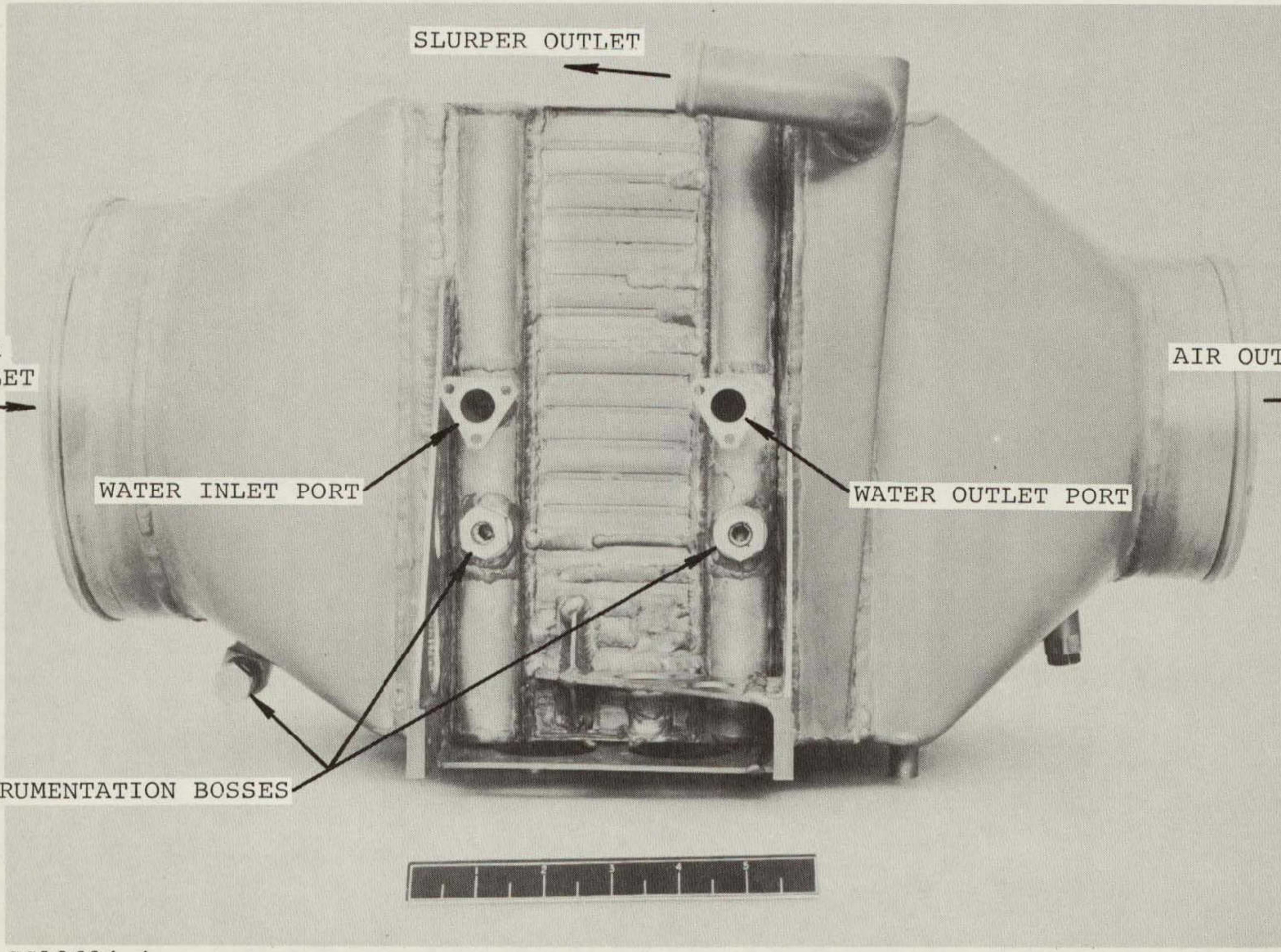
SS12623-4

FIGURE 20 SECONDARY SIDE



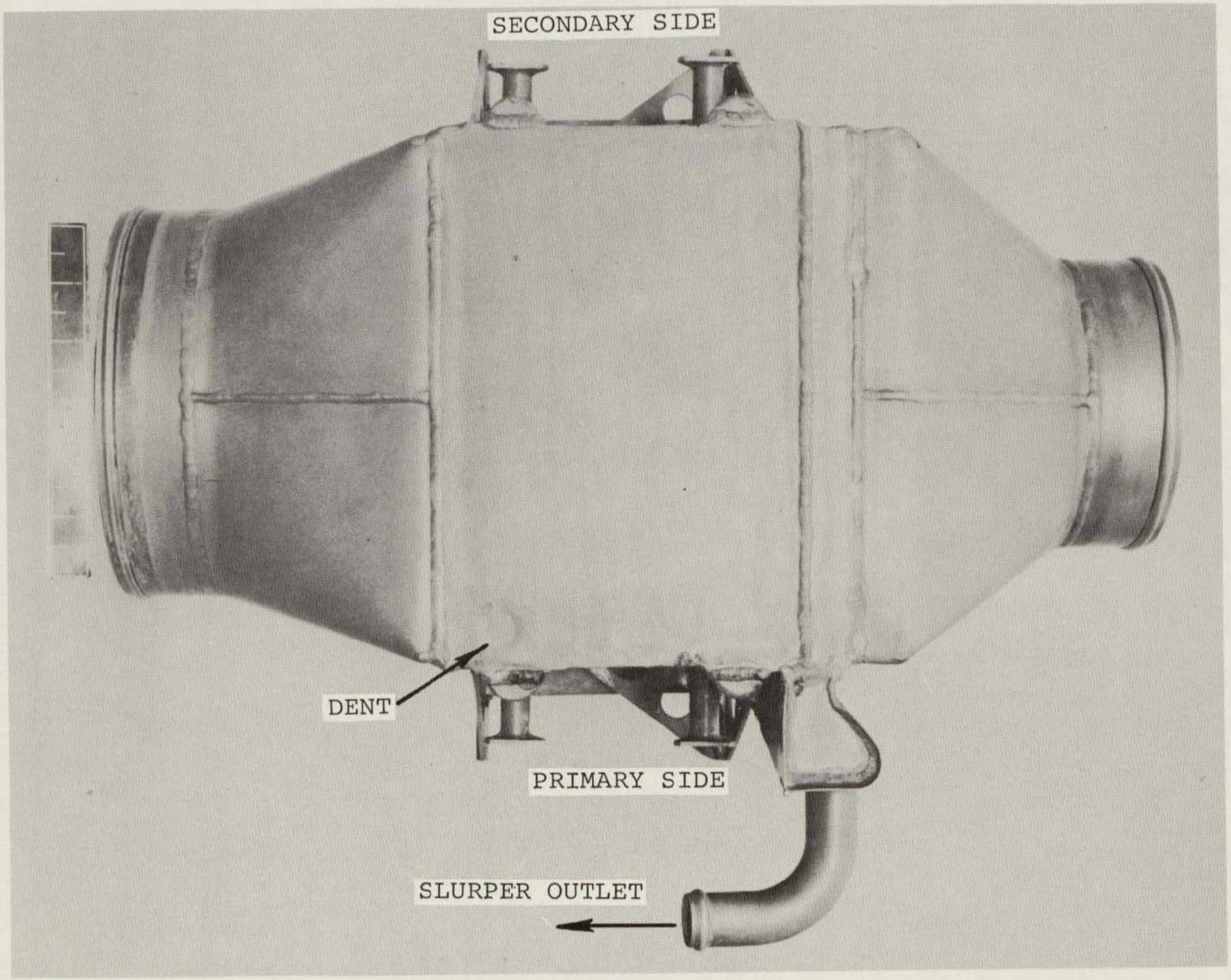
SS12620-4

FIGURE 21   BOTTOM VIEW



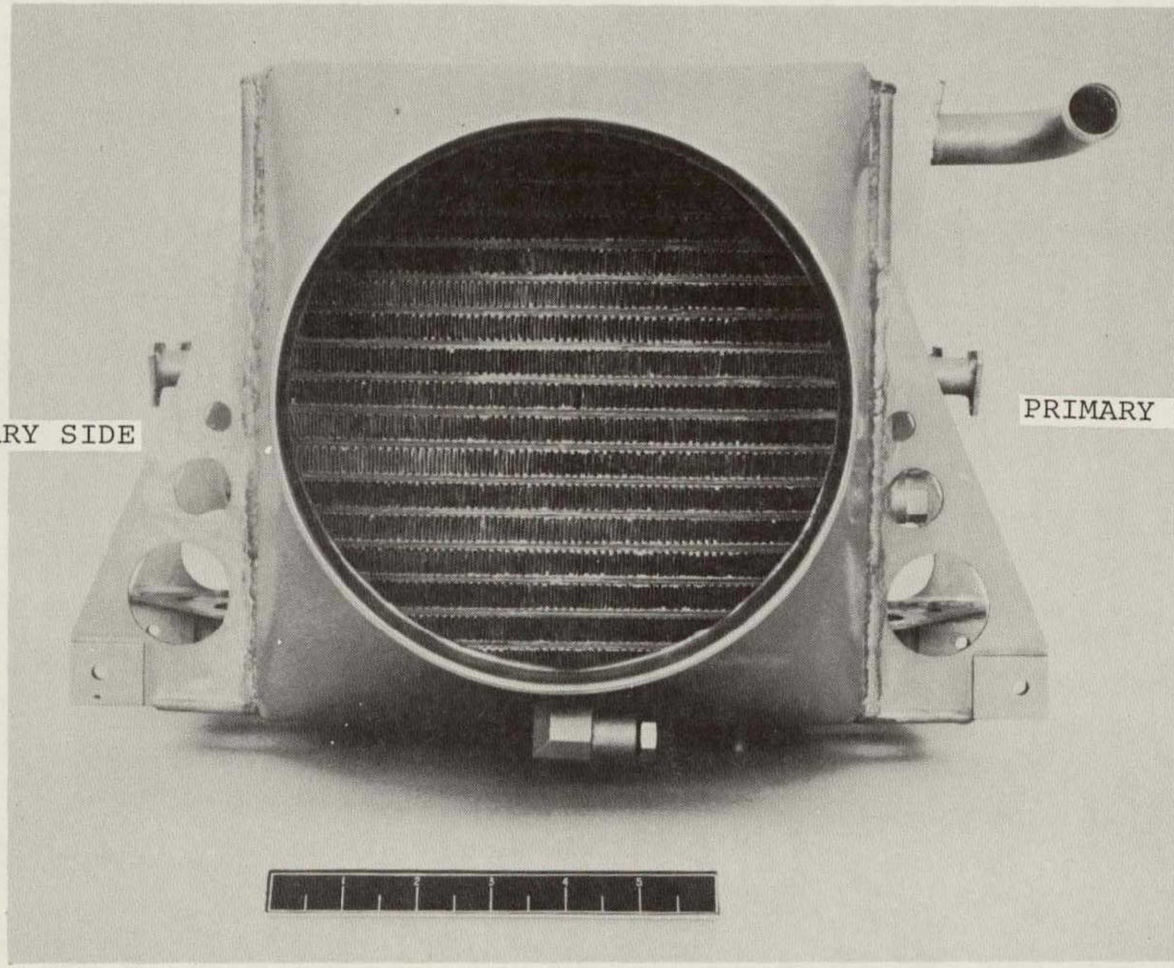
SS12624-4

FIGURE 22 PRIMARY SIDE



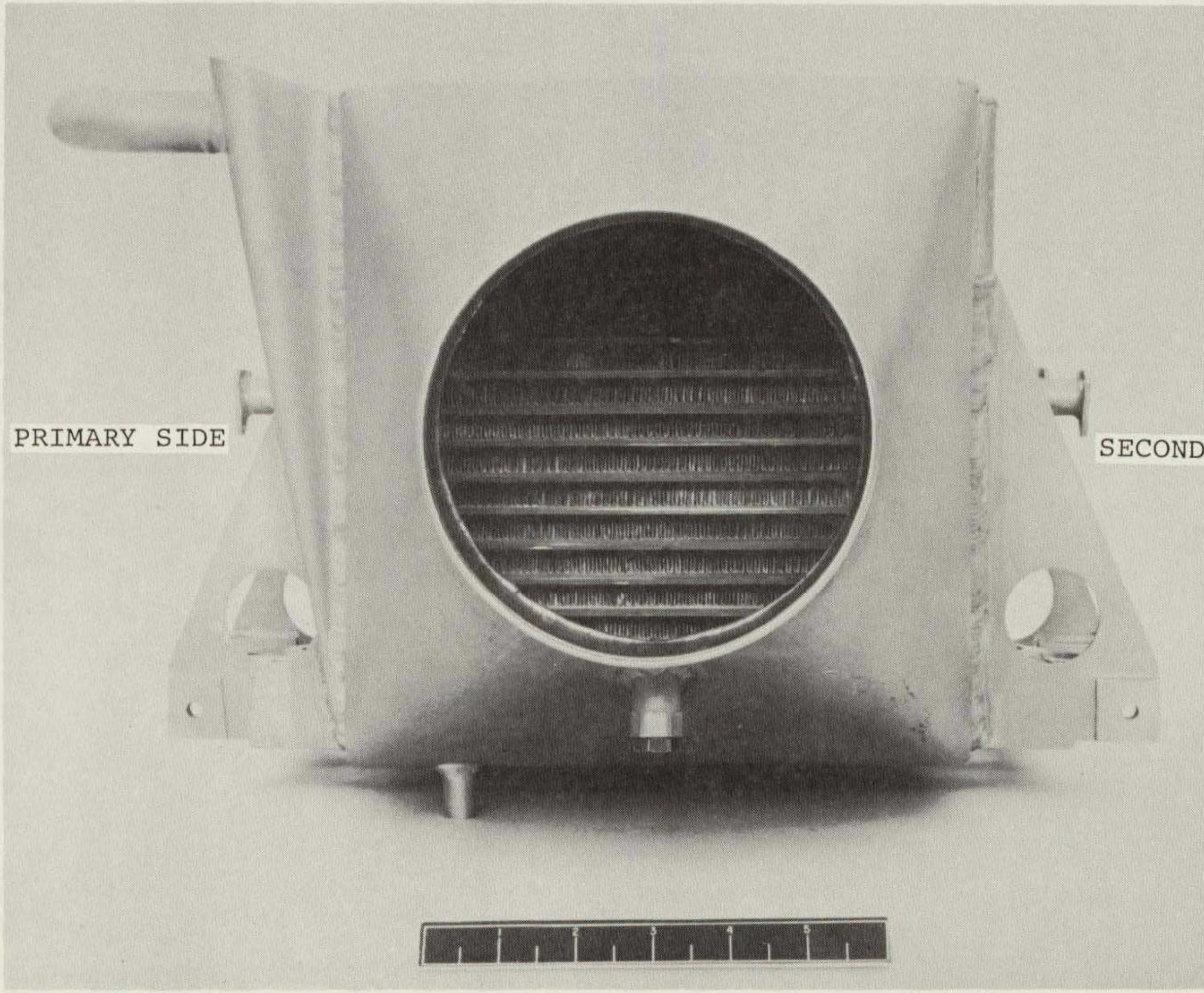
SS12618-4

FIGURE 23 TOP VIEW



SS12621-4

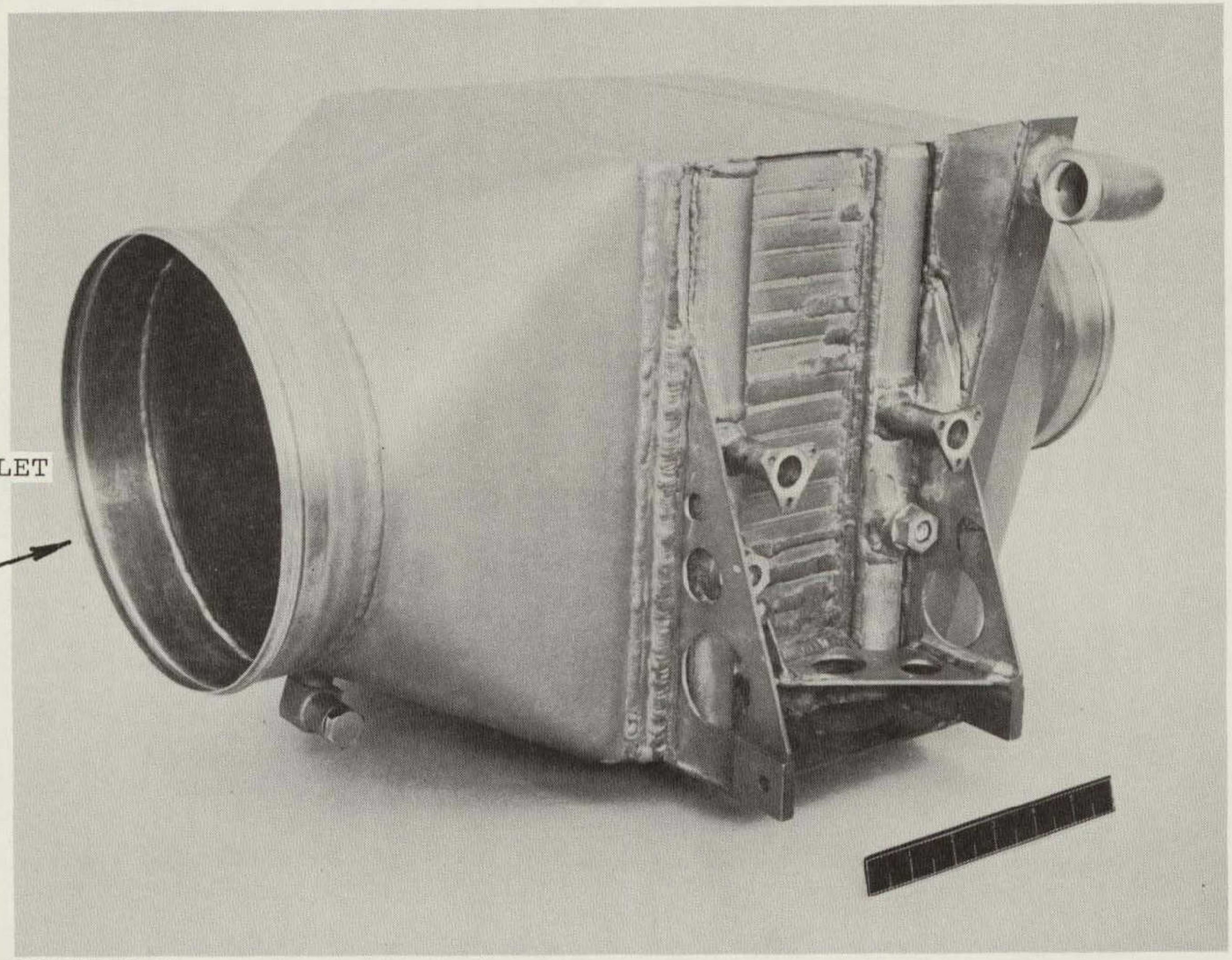
FIGURE 24 AIR INLET



SS12622-4

FIGURE 25 AIR OUTLET

AIR INLET



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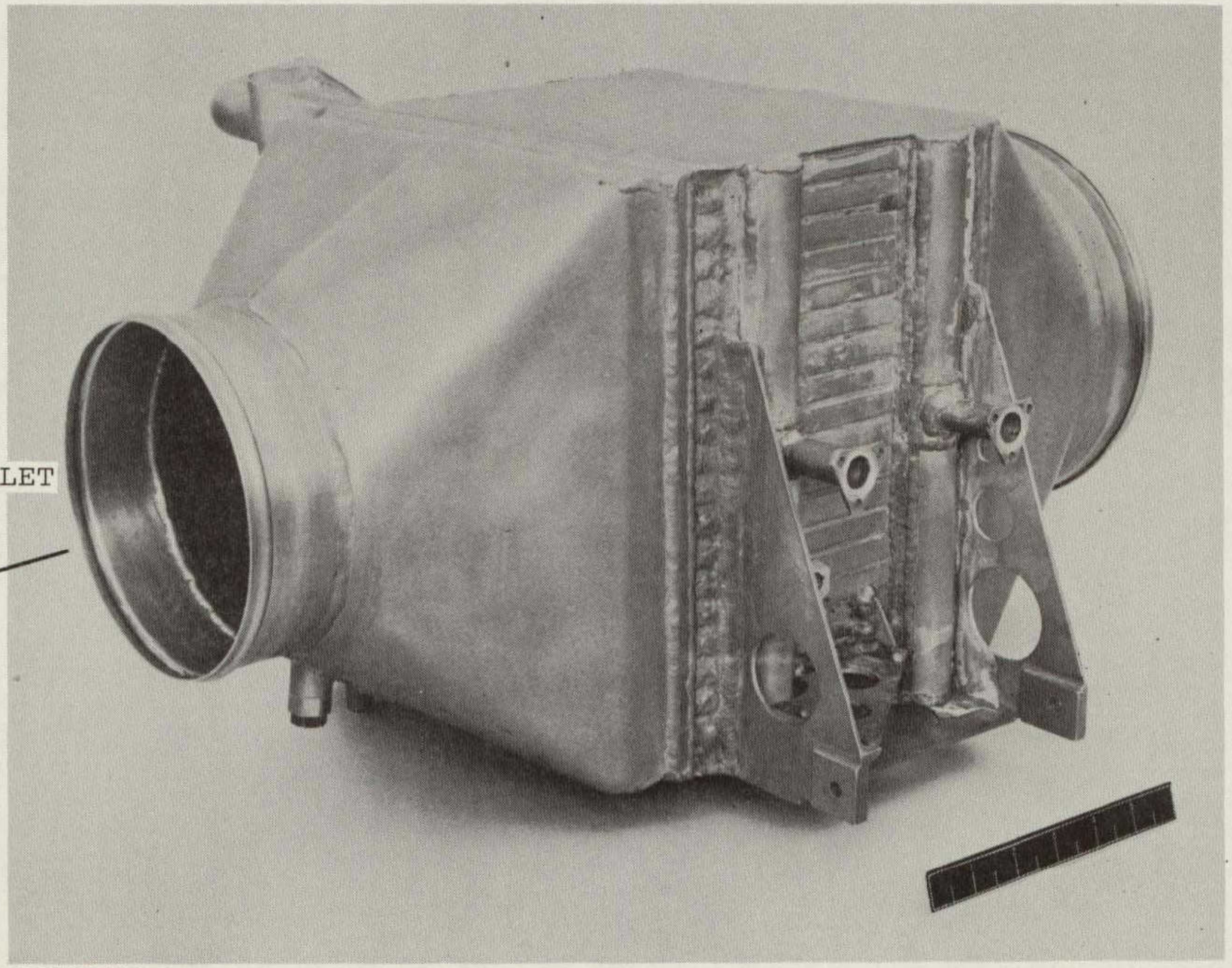

SS12617-4

FIGURE 27 3/4 VIEW - SECONDARY SIDE

Proof and Leakage

Both the primary and secondary water loops were subjected individually to 722 kPa (90 psig) pressure and checked for visible distortion; none was apparent.

In order to calculate a leak rate accurately, the volume of the test article must be known. An accurate method of determining volume is by discharging a known volume at a specific pressure into the unknown volume and noting the new pressure. The unknown volume can then be calculated. Figure 28 shows the setup for volume determination. The procedure followed was:

a. Open valve C, close valve B, open valve A, and pressurize to 793 kPa (115 psia) and record pressure.

b. Close valves A and C, open valve B, and allow pressure to stabilize. Record pressure.

c. Repeat (a) and (b) twice for a total of three times.

To determine the volume of the primary coolant side, a known volume of 1,028 cc (62.73 in^3) was used at a pressure of 790.8 kPa (114.7 psia). Pressure after discharge was 467.5 kPa (67.8 psia).

From $P_1 V_1 + P_2 V_2 = P_3 (V_1 + V_2)$

where: P_1 is pressure in known volume, kPa
V_1 is known volume, cc
P_2 is ambient pressure, kPa
V_2 is unknown volume, cc
P_3 is stabilized pressure, kPa

The volume of the heat exchanger coolant circuit is calculated:

$$V_2 = \frac{V_1(P_3-P_1)}{P_2-P_3} = 1,028 \frac{(467.5-790.8)}{101.4-467.5} = 907.97 \text{ cc}$$

The volume of the secondary side was presumed to be the same. The volume of the air side was calculated to be 25,077 cc (1,530 in^3). Pressure decay tests of the primary and secondary coolant loops showed similar results; a delta P of 4.826 kPa (0.7 psi) and 2.758 kPa (0.4 psi) respectively.

Using the relationship:

$PV = WRT$, the leak rate can be determined:

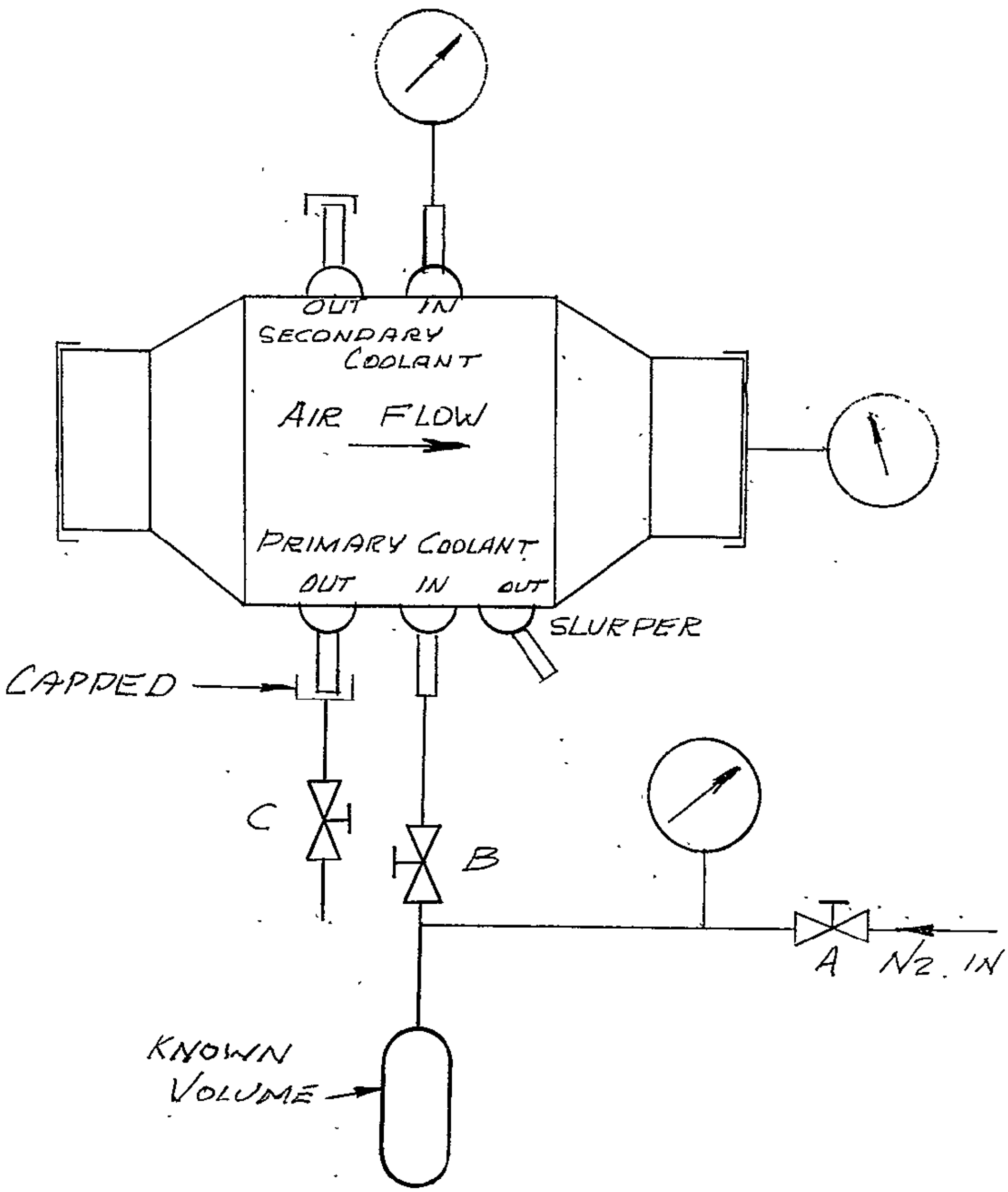

FIGURE 28 CORE VOLUME DETERMINATION SETUP

$W_1 = \frac{P_1 V}{RT}$ = Conditions at start of test

$W_2 = \frac{P_2 V}{RT}$ = Conditions at end of test

Then the gas lost through leakage is:

$$W_1 - W_2 = P_1 \frac{V}{RT} - P_2 \frac{V}{RT}$$

$$\text{Delta } W = (P_1 - P_2)\left(\frac{V}{RT}\right)$$

$$\text{Delta } W = \frac{\text{Delta } PV}{RT}$$ (where T is maintained constant for the test)

where W = mass of gas at pressure P and temperature T
V = volume of test article
R = universal gas constant

If we divide delta W by density (p) and time (t) and let $\frac{\Delta W}{pt}$ = lr then the leak rate = lr = $\frac{\Delta P}{RTpt}$ cc/t

in S.I. units lr = $2.619 \frac{\Delta P}{Tt}$ for coolant side

= $72.318 \frac{\Delta P}{Tt}$ for air side

in U.S. units lr = $32{,}701.35 \frac{\Delta P}{Tt}$ for coolant side

= $902{,}960.6 \frac{\Delta P}{Tt}$ for air side

The leak rates calculated for the primary and secondary sides were 1.43 cc/min and 0.82 cc/min. These leak rates are approximately ten times less than previously noted, although a submersion test showed the leak to be internal (between water passes) and presumably the same leak discovered earlier.

The leak rate calculated for the air side was 51.28 cc/min. This test was not observed by the Program Engineer but based upon later observations is believed to represent fixture leakage rather than heat exchanger leakage.

Performance

Performance testing of the lightweight long life heat exchanger was performed to demonstrate that the heat exchanger is interchangeable with Shuttle CEI Item 10 P/N 705504.

Table IV presents the heat exchanger design requirements together with a representative primary and redundant loop data point.

This demonstrates the units overall compliance with the design requirements. Table V summarizes the recorded heat exchanger performance data for each of the points tested. These data are discussed below.

To maintain a systematic approach, the data from each test was reduced according to analytical procedures outlined in the Master Test Plan. In addition, the performance of the heat exchanger was evaluated on the basis of its effectiveness value, ϵ, which is defined as:

$$\epsilon = \frac{T_{Air\ In} - T_{Air\ Out}}{T_{Air\ In} - T_{Water\ In}}$$

The heat exchanger effectiveness is a non-dimensional grouping which possesses readily visualized physical significance since it compares actual attained heat transfer to maximum theoretical values.

A preliminary review of all performance test data indicated that the heat balances were within 10 percent. Although slight variances between inlet and outlet dew pointer readings were observed during noncondensing runs, this critical instrumentation generally could be relied upon to give accurate readings in the condensing mode.

Figure 29 presents noncondensing heat exchanger effectiveness as a function of total air flow.

This shows that for the dry operating mode the unit achieves a relatively high effectiveness level over the full range of air flow rate.

Figure 30 presents a plot of heat exchanger effectiveness versus percent latent heat load. Data is presented for the three nominal flow conditions:

PARAMETER	S. I. UNITS				ENGLISH UNITS			
	UNITS	DESIGN REQUIREMENT	REPRESENTATIVE PRIMARY LOOP POINT 13666 3B	REPRESENTATIVE REDUNDANT LOOP POINT 14141 3A	UNITS	DESIGN REQUIREMENT	REPRESENTATIVE PRIMARY LOOP POINT 13666 3B	REPRESENTATIVE REDUNDANT LOOP POINT 14141 3A
SENSIBLE HEAT TRANSFER RATE	WATTS	5232	5534	5303	BTU/HR	17842	18893	18106
LATENT HEAT TRANSFER RATE	WATTS	1029	1511	1485	BTU/HR	3509	5157	5070
AIR TEMP. IN (DRYBULB)	K	313	313	313	°F	104	104.2	103.6
AIR TEMP. IN (DEWPOINT)	K	287	287	287	°F	57.6	58.0	57.9
AIR TEMP. OUT (DRYBULB)	K	283	282	283	°F	50.1	47.8	49.4
AIR TEMP. OUT (DEWPOINT)	K	283	281	281	°F	50.1	46.8	47.0
AIR FLOW RATE	kg/HR	620	621.6	620	LB/HR	1366	1369	1365 6
AIR PRESSURE DROP (DRY)	PA	149.4 @ 636 kg/HR	149.5 @ 641 kg/HR *	149.5 @ 641 kg/HR **	IN. H_2O	6 @ 1400 LB/HR	6 @ 1411 LB HR	6 @ 1411 LB HR
AIR PRESSURE DROP (WET)	PA	199.3 @ 636 kg/HR	169.4 @ 641 kg/HR **	162 @ 620 kg/HR	IN. H_2O	.8 @ 1400 LB HR	68 @ 1411 LB HR	65 @ 1366 LB HR
WATER TEMP-IN	K	279	278	279	°F	43.5	42.0	43.4
WATER TEMP-OUT	K	291	291	292	°F	64.4	64.9	66.3
WATER FLOW RATE	kg/HR	458	457.5	458.7	LB/HR	1009	1007.6	1010.3
WATER PRESSURE DROP	FA	844 @ 431 kg/HR	.914 @ 457 kg/HR	909 @ 459 kg/HR	PSI	1.2 @ 950 LB HR	1.3 @ 1007.6 LB HR	1.3 @ 1010 LB HR

* DRY POINT 14140 2
** WET POINT 14142 2

TABLE IV DESIGN REQUIREMENTS AND REPRESENTATIVE TEST DATA POINTS

TABLE V PERFORMANCE DATA LIGHT–WEIGHT LONG LIFE HEAT EXCHANGER II

LOG NUMBER	TEST POINT		ṁ AIR		T AIR–IN		T D.P.–IN		T AIR–OUT		T D.P.–OUT		ṁ H_2O		T H_2O–IN		T H_2O–OUT		Q SENSIBLE		Q LATENT		Q TOTAL (AIR)		Q H_2O		HEAT INBALANCE	AIR
—	P=PRIM S=SECON		kg/HR	LB/HR	K	°F	K	°F	K	°F	K	°F	kg/HR	LB/HR	K	°F	K	°F	WATTS	BTU/HR	WATTS	BTU/HR	WATTS	BTU/HR	WATTS	BTU/HR	%	%
13662	1	P	207.7	457.5	299	79.8	286	55.5	280	45.0	279	43.0	208.6	459.4	278	42.1	285	53.8	1139	3888	525	1792	1664	5680	1655	5651	.56	92.0
13662	1A	P	209.5	461.4	299	79.8	286	55.5	278	42.1	279	43.0	208.7	459.8	279	42.4	285	53.9	1145	3910	530	1809	1675	5718	1667	5690	.50	92.3
13662	1B	P	209.5	461.4	299	79.4	286	55.9	280	44.9	279	43.0	208.7	459.8	278	41.9	285	53.4	1139	3888	552	1885	1691	5773	1639	5594	3.10	91.9
14143	1	P	209.2	460.8	299	79.9	285	53.6	280	44.8	279	42.8	208.6	459.4	278	42.1	285	53.2	1156	3948	448	1530	1605	5479	1511	5159	5.86	92.5
14140	1	F	209.2	460.8	299	79.6	259	7.0	279	43.6	256	1.0	209.5	461.4	278	41.9	283	50.5	1162	3967	0	0	1162	3967	1149	3922	1.14	96.3
13664	2	P	641.2	1412.4	302	85.2	287	58.0	284	52.7	284	51.9	465.6	1025.6	282	49.0	290	62.7	3279	11196	907	3096	4187	14294	4186	14291	.03	89.3
13664	2A	F	641.2	1412.4	303	85.4	287	58.0	284	52.9	284	51.8	465.0	1024.3	282	49.1	290	62.8	3276	11184	918	3134	4194	14319	4160	14202	–.02	88.9
13664	2B	P	641.2	1412.4	303	85.6	287	58.0	284	52.9	284	51.8	465.8	1026.0	282	49.1	290	62.8	3296	11254	913	3116	4209	14370	4156	14189	1.26	88.9
14142	2	F	640.7	1411.2	302	85.3	286	55.5	284	52.1	283	50.5	465.6	1025.5	282	49.0	·289	61.9	3349	11433	712	2430	4061	13863	3866	13198	4.79	91.3
14140	2	P	641.0	1411.8	303	85.5	269	24.5	283	50.9	268	22.5	465.4	1025.0	282	49.1	289	60.8	3419	11673	0	0	3419	11673	3513	11992	–2.73	94.5
13666	3	F	620.3	1366.2	313	104.2	279	42.3	282	47.9	281	46.9	456.6	1005.8	279	42.3	291	65.1	5485	18725	1497	5110	6982	23836	6835	23335	2.10	90.3
13666	3A	F	621.3	1368.6	313	104.4	288	58.5	282	47.9	281	47.0	457.5	1007.7	279	42.3	291	65.0	5527	18870	1564	5340	7092	24212	6868	23446	3.20	90.4
13666	3B	F	621.6	1369.2	313	104.2	287	58.0	282	47.8	281	46.8	457.5	1007.6	278	42.0	291	64.9	5534	18893	1511	5157	7045	24050	6856	23406	2.60	90.5
14140	3	F	619.4	1364.4	313	104.5	270	26.0	281	46.1	268	23.0	457.9	1008.6	279	43.2	290	62.9	5606	19139	0	0	5606	19139	5790	19768	–3.30	95.1
14142	3	F	620.0	1365.6	313	103.8	287	57.7	282	49.2	282	48.0	458.4	1009.6	279	43.6	292	65.6	5338	18224	1341	4578	6679	22802	6530	22292	2.24	90.5
14141	3	S	620.0	1365.6	313	104.2	267	21.0	265	46.6	265	18.0	458.4	1009.6	279	43.6	291	63.8	5500	18778	0	0	5500	18778	5974	20394	–8.60	94.6
14141	3A	S	620.0	1365.6	313	103.6	287	57.9	283	49.4	281	47.0	458.7	1010.3	279	43.4	292	66.3	5503	18106	1485	5070	6789	23176	6771	23116	.26	89.8
13668	4	S	619.4	1364.4	313	104.1	287	58.0	281	48.3	281	46.0	457.6	1007.9	278	42.0	291	65.5	5450	18607	1585	5411	7046	24056	6958	23753	1.26	89.5
13668	4A	S	620.0	1365.6	313	104.3	288	58.5	282	48.5	281	46.5	458.0	1008.9	278	42.0	292	65.6	5467	18664	1620	5531	7087	24196	6954	23741	1.88	89.5
13668	4B	S	620.3	1366.2	313	104.7	288	59.5	283	49.7	282	47.8	457.9	1008.7	279	43.5	292	66.6	5390	18402	1628	5558	7019	23962	6825	23300	2.76	89.6
13668	4C	S	620.0	1365.6	313	104.6	288	59.5	282	49.4	281	47.5	457.9	1008.7	279	43.5	292	66.5	5398	18430	1669	5697	7067	24126	6804	23229	3.70	89.9

FOLDOUT FRAME 1

FOLDOUT FRAME 2

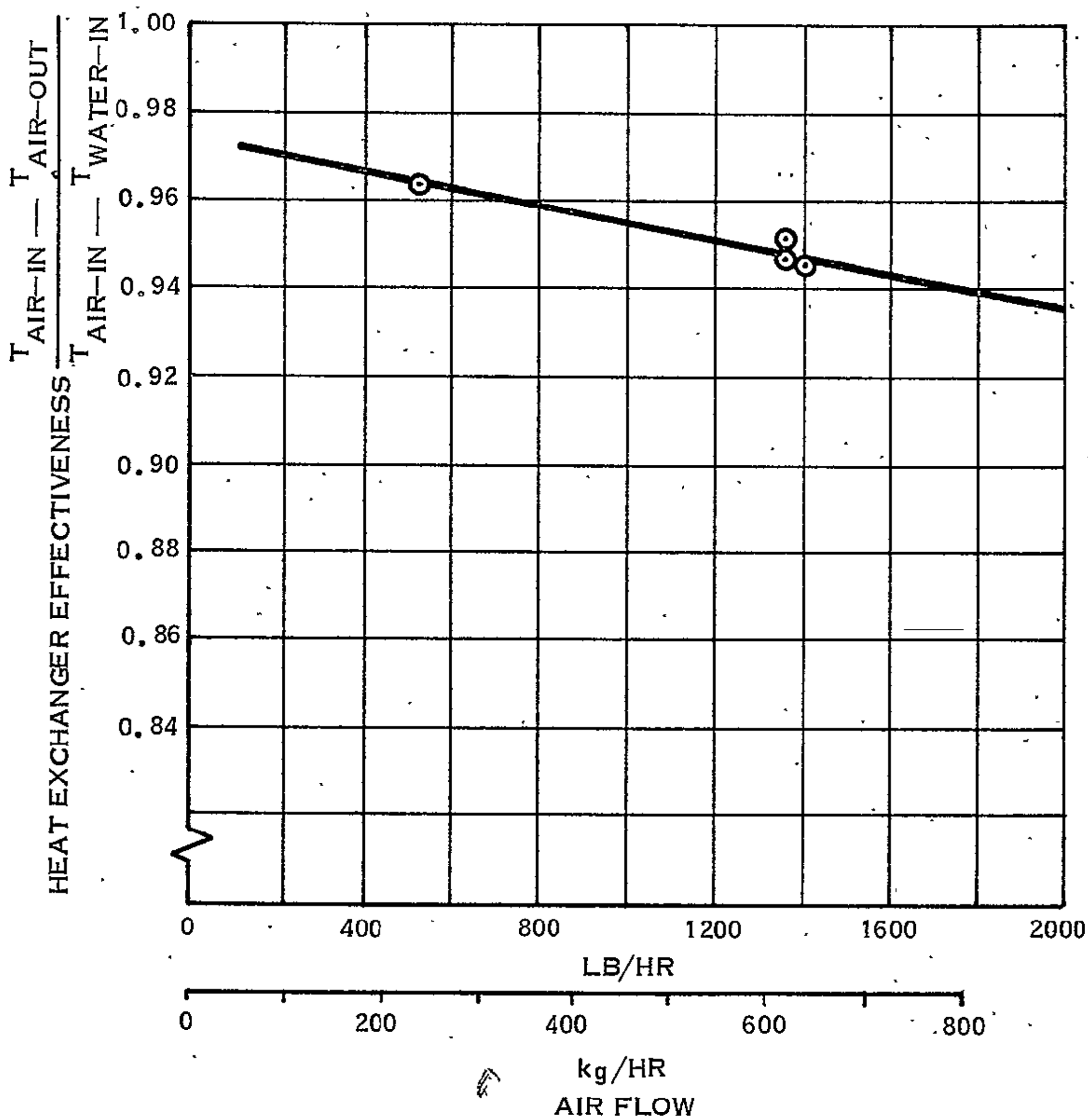

FIGURE 29 HEAT EXCHANGER EFFECTIVENESS VS. AIRFLOW (DRY)

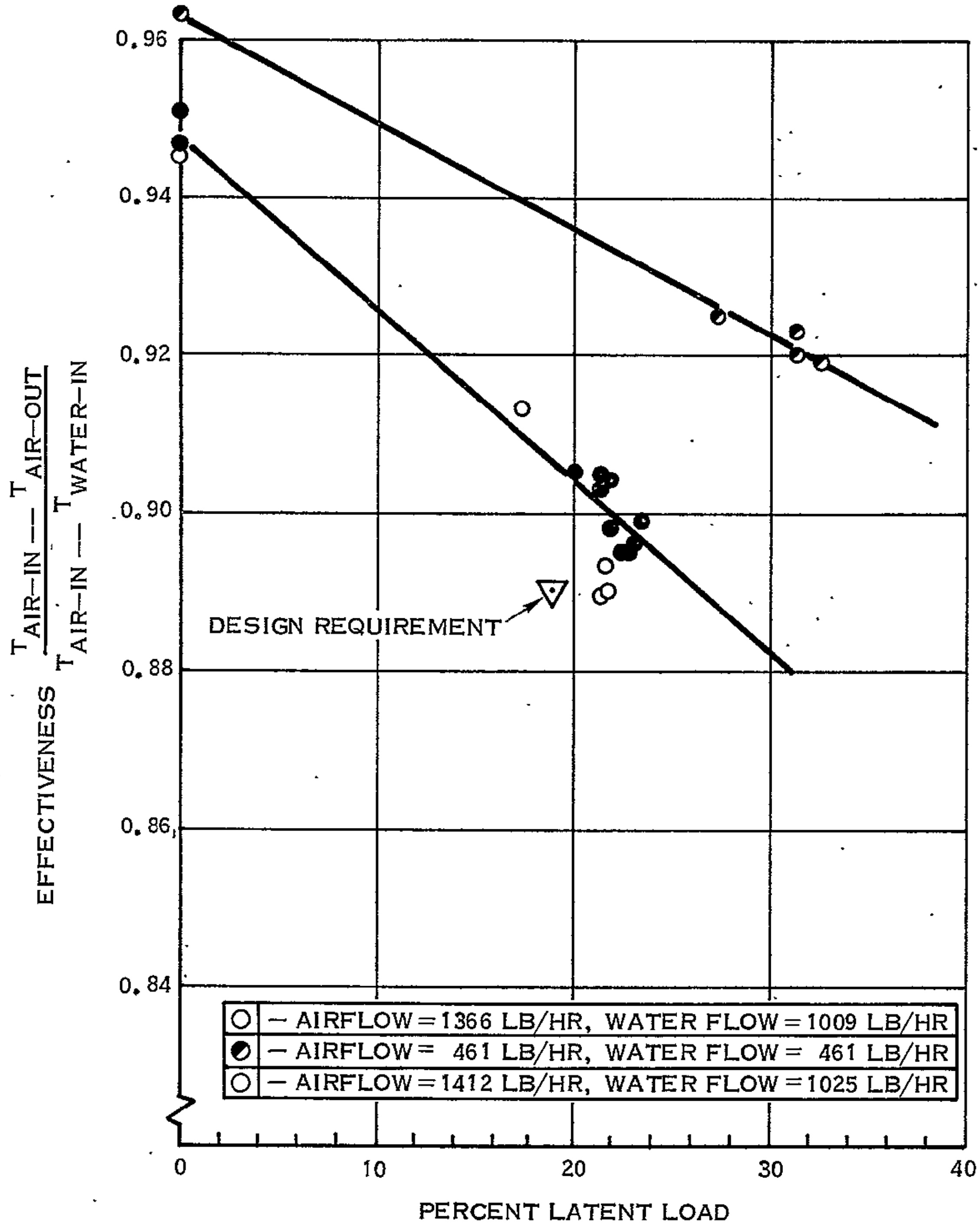

FIGURE 30 HEAT EXCHANGER EFFECTIVENESS VERSUS PERCENT LATENT LOAD

2. Air Flow = 620 kg/hr (1,366 lb/hr), Water Flow = 458 kg/hr (1,009 lb/hr)

3. Air Flow = 640 kg/hr (1,412 lb/hr), Water Flow = 465 kg/hr (1,025 lb/hr)

The two latter conditions are sufficiently close together that one line was used to represent the data trend. These data demonstrated compliance with the design requirement, as represented by an effectiveness value.

The decrease in effectiveness as latent load is increased is normal and results primarily from air flow maldistribution caused by water droplets collecting on the airway fin surface. This effect is minimized through the use of hydrophilic coatings and operation with the functional water collection device.

Figure 31 is a plot of heat exchanger air side dry pressure drop versus flow rate. The design point is again included for reference and shows that the unit operates within its design limitations. As the heat exchanger switched to the condensing mode, the air side pressure drop increased over the dry value, as shown in Figure 32.

The heat exchanger water pressure drop was found to be 8.27 kPa (33.2 inches H_2O) at 431.3 kg/hr (950 lb/hr) which meets the design requirement for the unit.

Post Performance Proof and Leakage

The leakage tests were performed per the test plan and showed no leakage in 30 minutes for either water circuit and 5.7 cc/min leakage on the air side. Because of the differences noted in coolant side leakage, this test was rerun.

It was found that coolant side leakage had decreased to an extent where a 30 minute test was too short to determine the rate. The primary side was tested to achieve a 6.894 kPa (1.0 psi) decrease in pressure. Two hundred twelve minutes were required resulting in a rate of 0.29 cc/min. To confirm this result, the unit was submerged, and the escaping gas was trapped. In one hour 8.0 cc's were collected or 0.13 cc/min, confirming the pressure decay test result. This rate, again, is appreciably below the rate previously measured and probably represents gradual closure of the leak by aluminum corrosion products. On September 14, 1976 this leakage was again measured and had further decreased to 0.03 cc/min.

After correcting air side fixture leakage, the rate was found to be 5.69 cc/min, and the leak was located at a weld in the slurper header, see Figure 33. This leak was epoxy sealed after all other tests were completed.

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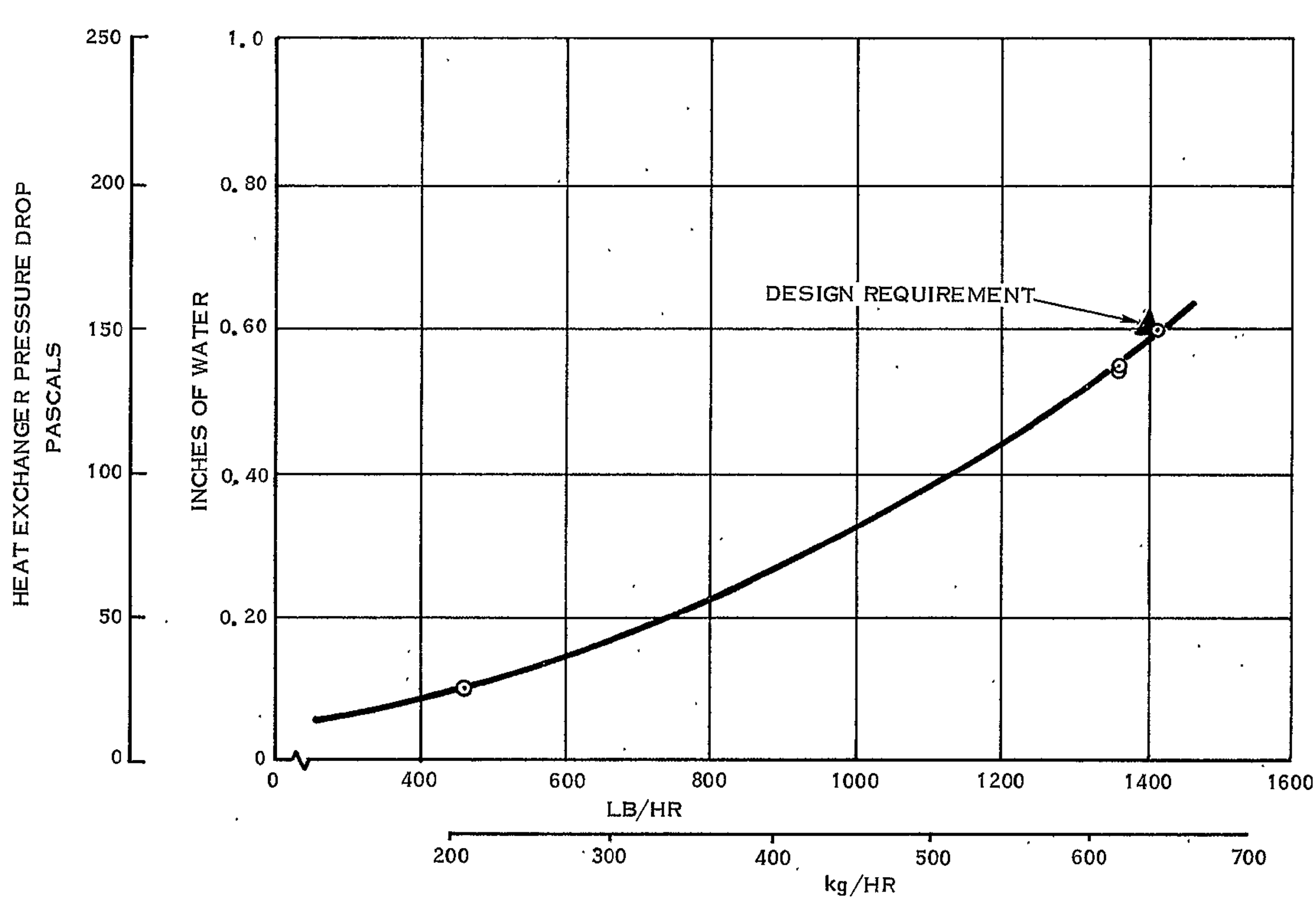


FIGURE 31 AIRSIDE PRESSURE DROP (DRY)

SVHSER 7077

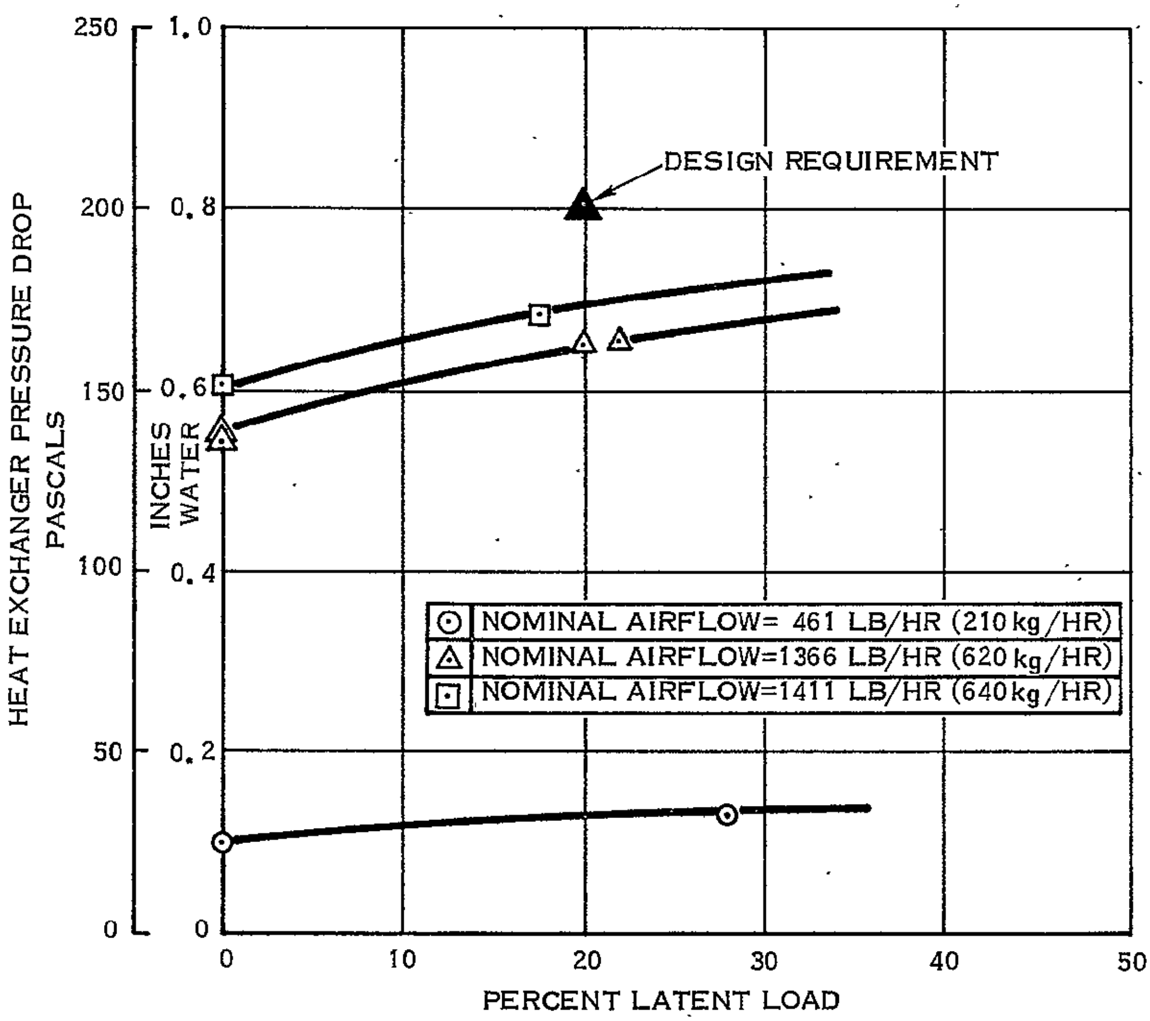
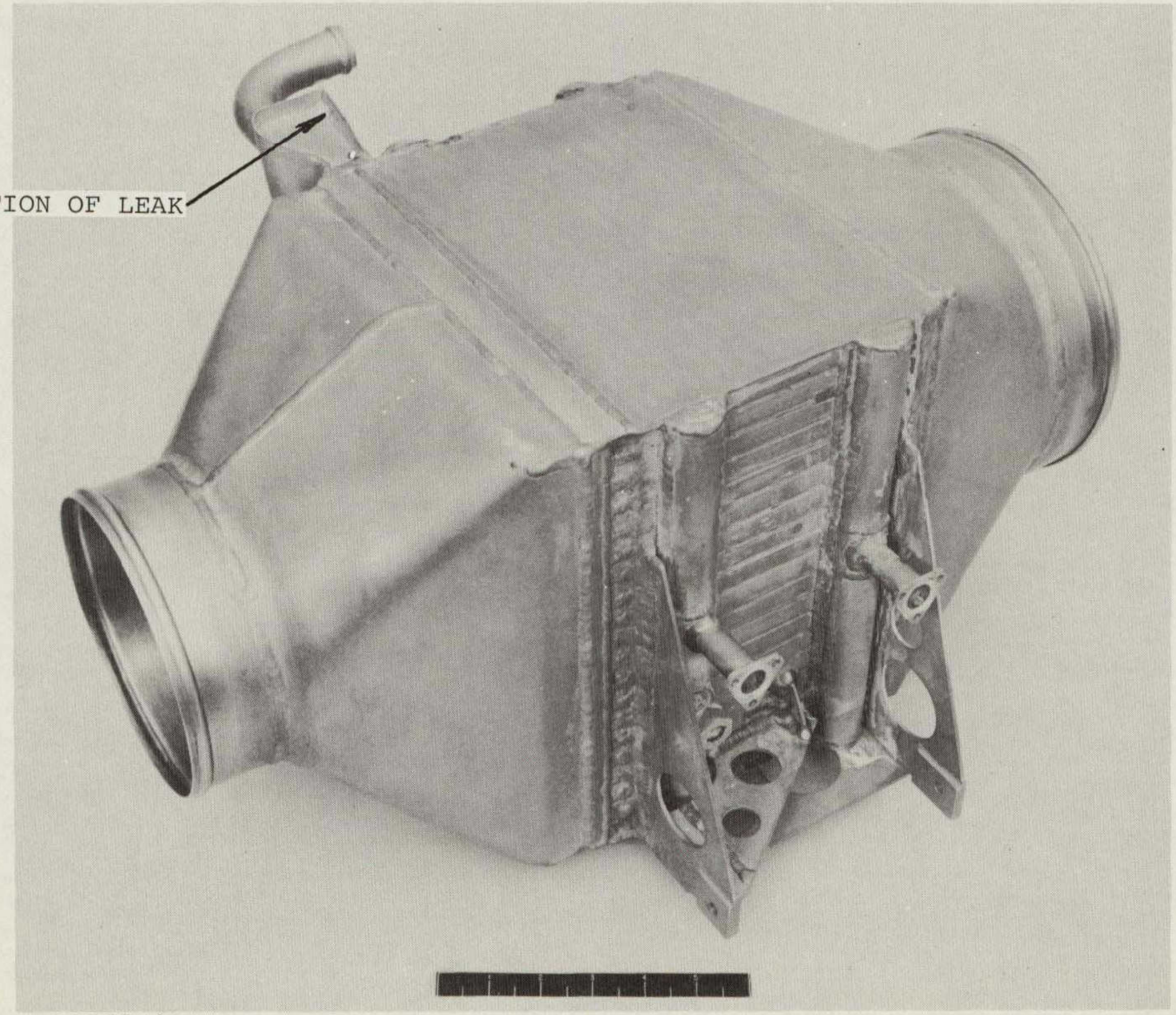


FIGURE 32 AIRSIDE PRESSURE DROP VS. LATENT LOAD



SS12567-4

FIGURE 33 AIR SIDE LEAKAGE

Coating Wettability

The time-to-wet and contact angle test results were virtually unchanged from pretest conditions.

Weight

Two post test dry and weigh cycles showed the weight of the heat exchanger to be unchanged at 8.736 kg (19.26 lbs).

Post Test Visual Examination

As previously noted, no discernible differences were noted, and Figures 18 through 25 are post test photographs.

APPENDIX A

PRESSURE DROP CALCULATIONS

HX AIR SIDE PRESSURE DROP CALCULATIONS

INLET HEADER

$$1411 \frac{\#}{HR} = .3919 \frac{\#}{SEC.} = 5.429 \frac{FT^3}{SEC} \qquad \rho = 0.0722 \frac{\#}{FT^3}$$

$$\text{INLET HEADER AREA} = \frac{\pi (8)^2}{4 \cdot 144} = 0.3491 \; FT^2$$

$$\text{FLOW VELOCITY} = \frac{Q}{A} = \frac{5.429}{0.3491} = 15.6 \frac{FT}{SEC}$$

$$HL = \frac{\rho V^2}{2g_c} = \frac{.0722 \; (15.6)^2}{64.4 \quad 144} = .00188 \; Psi$$

ENTRANCE & EXIT EFFECTS : $\Delta P = \frac{\rho V^2}{2g_c}\left[(K_c + 1 - \sigma^2) - (1 - \sigma^2 - K_e)\frac{v_2}{v_1}\right]$

$$\Delta P = \frac{.0722 \; (10.9)^2}{64.4 \quad 144}\left[(1.08 + 1 - .481) - (1 - .481 + .5) \, .927\right]$$

$$\Delta P = 0.0006 \; Psi$$

OUTLET HEADER

$$1411 \frac{\#}{HR} = .3919 \frac{\#}{SEC} = 5.034 \frac{FT^3}{SEC} \qquad \rho = 0.07786$$

$$A = \frac{\pi (6)^2}{4 \; 144} = 0.1963 \; FT^2 \quad \text{HEADER AREA}$$

$$\text{FLOW VELOCITY} = \frac{Q}{A} = \frac{5.034}{.1963} = 25.64 \frac{FT}{SEC}$$

$$HL = \frac{\rho V^2}{2g_c} = \frac{.07786 \; (25.64)^2}{64.4 \quad 144} = 0.0055 \; Psi$$

0.5 VELOCITY HEAD LOSS FOR OUTLET HEADER = .00276 Psi

TOTAL AIR SIDE PRESSURE LOSS

CORE LOSS	.01649 Psi
INLET HEADER	.00188 Psi
ENTRANCE & EXIT EFFECTS	.00060 Psi
OUTLET HEADER	.00276 Psi
	.02173 Psi = .601 " H_2O

COOLANT PRESSURE LOSS

$$725 \frac{\#}{HR} = 0.201 \frac{\#}{SEC} = 0.00323 \frac{FT^3}{SEC} \qquad \rho = 62.4 \frac{\#}{FT^3}$$

$$\text{INLET LINE AREA} = \frac{\pi (.4)^2}{4 \quad 144} = 0.000872 \ FT^2$$

$$\text{FLOW VELOCITY} = \frac{Q}{A} = \frac{.00323}{.000872} = 3.70 \frac{FT}{SEC}$$

$$HL. = \frac{\rho V^2}{2 g_c} = \frac{62.4 (3.7)^2}{64.4 \quad 144} = 0.09212 \ PSI$$

$$1.5 \times HL = 0.1382 \ PSI$$

INLET & OUTLET HEADERS	=	0.1382 PSI
CORE LOSS	=	0.5944 PSI
TOTAL		0.7326 PSI

APPENDIX B

TEST PLAN

LIGHTWEIGHT LONG LIFE HEAT EXCHANGER
FLIGHT CONFIGURATION

MASTER TEST PLAN

PREPARED UNDER CONTRACT NAS 9-14494

BY

HAMILTON STANDARD
DIVISION OF UNITED TECHNOLOGIES

WINDSOR LOCKS, CONNECTICUT

FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

HOUSTON TEXAS

JUNE 1975

Prepared by E.K. Moore
E.K. Moore, Program Engineer

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F.H. Greenwood, Program Manager

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1.0 SCOPE

This test plan defines the testing of a Lightweight Long Life Heat Exchanger (LLLHX-II) being conducted for the National Aeronautics and Space Administration Lyndon B. Johnson Space Center, NASA Contract 9-14494.

2.0 APPLICABLE DOCUMENTS

2.1 Government

MIL-P-27401 Propellant pressuring Agent, Nitrogen

2.2 Hamilton Standard

HS 3150	Cleanliness Levels, High - Processing, Testing and Preservation of parts subject to
SVHS TBD	Coating Hydrophilic. Aluminum Heat Exchangers.
SVSK 90348	Drawing, Heat Exchanger Condenser.
SV 755504	Drawing, Humidity Control Heat Exchanger, Item 10.

3.0 GENERAL

3.1 Item Description - The Lightweight Long Life Heat Exchanger (LLLHX-II), Hamilton Standard P/N SVSK 90348-1, is designed to be completely interchangeable with the Shuttle condensing heat exchanges CEI 10. As tested and delivered, the LLLHX does not include insulation and flight instrumentation. The component was designed to the following conditions:

Outlet Total Pressure, psia	14.8
Gas Flow, lbs/Hr	1366
Gas Inlet Temperature, °F	104
Gas Outlet Temperature, °F	50.1
Inlet Dew Point °F	57.6
Water Inlet Temperature °F	43.5
Water Flow, lbs/Hr	1009
Water Outlet Temperature (ref) °F	64.4
Max. Gas Side Wet ΔP, in. H_2O	0.8
Max. Gas Side Dry ΔP, in. H_2O	0.6
Q Sensible, BTU/Hr	17,842
Q Latent, BTU/Hr	3,509
Weight, lbs max.	20.8
Water ΔP, in. H_2O	38.8
Vibration	Fig 1

The heat exchanger is a fluxless brazed, aluminum unit incorporating aluminum clad titanium parting sheets. It contains nineteen parallel, single pass gas passages for condensing moisture and cooling gas. It also contains twenty, four pass primary water cooling passages and twenty, four pass secondary (redundant), water cooling passages. Mounting and connection points are identical to Shuttle CEI item 10. The weight, including insulation and flight instuments is calculated to be 23.72 lbs. nominal or 56.4% of the comparable Shuttle stainless steel unit.

3.2 Test Purpose - The purpose of the test program is to demonstrate that the item is interchangeable with Shuttle P/N SV75504 item 10, and is capable of withstanding the vibratory loads of Figure 1.

3.3 Tests - After completion of the fabrication of the item, which includes proof and leakage tests, the item shall be subjected to the following tests in the sequence specified:

Test	Title	Test per paragraph
1.	Weight	4.1
2.	Visual Examination	4.2
3.	Coating Wettability	4.3
4.	Proof and Leakage	4.4
5.	Performance	4.5
6.	Proof and Leakage	4.4
7.	Vibration	4.6
8.	Proof and Leakage	4.4
9.	Performance	4.5
10.	Coating Wettability	4.3
11.	Weight	4.1
12.	Post Test Visual Examination	4.2

3.4 Test Facilities - Unless otherwise indicated, all testing shall be conducted in the Space System Department test laboratories at Hamilton Standard. Alternate facilities may be used, if necessary, if approved in writing by the cognizant Program Engineer.

4.0 TEST REQUIREMENTS

Test objectives, descriptions, procedures, and pass-fail criteria are contained in the following paragraphs. Deviations may only be made if authorized in writing by the cognizant Program Engineer.

4.1 Weight

4.1.1 Objective - The objective of the weight measurement is to establish that the design requirement of a weight no greater than 60% of the comparable Shuttle HX has not been exceeded or to detect any weight change resulting from testing.

4.1.2 Description

4.1.2.1 Test Setup - The item shall be weighed on a scale having a full scale accuracy of at least 1% and a range no greater than 100 lbs. and capable of being read to ± 0.1 lbs. Prior to weighing, a vacuum chamber shall be used to dry the item thoroughly.

4.1.2.2 Procedure - The item without port closures and free of all extraneous material, shall be dried for 24 hours minimum at a pressure of 1500 microns maximum and a temperature of 60°F minimum. Within one hour after the drying period and without wetting the item, weigh and record the item weight on Log of Test. HSF 175.1A per Figure 2. Repeat the drying and weighing sequence. The two recorded weights shall agree within 0.1 lb. If the weights do not agree, the drying - weighing sequence shall be repeated until agreement is reached with two consecutive readings.

4.1.3 Pass - Fail Criteria - A weight greater than 20.8 lbs. shall require approval from the NASA to proceed with testing.

4.2 Visual Examination

4.2.1 Objective - The objective of the visual examination is to define a baseline of the visual appearance of the heat exchanger, describing apparent defects or damage for comparison before and after test.

4.2.2 Description

4.2.2.1 Test Setup - The heat exchanger shall be placed on a well lighted, clean bench in the SSD laboratory or inspection department. It shall be free of chips, dirt and liquids and the ports shall be open. Photographs may be taken in the Photo Laboratory.

4.2.2.2 Procedure - The item shall be visually examined on exterior surfaces for evidence of dirt manufacturing residue, stains, dents, burns or other marks or blemishes. Inlet and outlet water ports shall be subjected to particular attention. Visual observations shall be recorded on a Log of Test. HSF 157.1A. Photographs shall be used to record the general appearance of the item and shall include sufficient views to show all six sides of the item. In particular, the surfaces of the inlet and outlet water ports shall be photographed as well as those portions of the hydrophilic coating that are readily photographed. In addition, the inlet and outlet of the air fins shall be photographed.

4.2.3 Pass - Fail Criteria

a. The item shall be free of all dirt, chips, residues and other foreign material.

b. Damage which could affect the performance or function of the unit shall be cause for rejection. The cognizant Program Engineer shall judge the suitability of the item for continued testing.

4.3 Coating Characteristics

4.3.1 Objective - The objective of the coating characteristics test is to establish a baseline against which deterioration of the hydrophilic coating can be measured and to demonstrate that the coating is acceptable.

4.3.2 Description

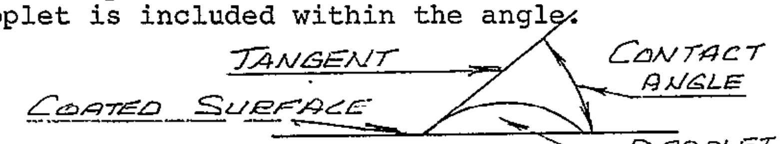
4.3.2.1 Test Setup - The characteristics test shall be performed on the dry heat exchanger on a clean dry well lighted bench. A 10X microscope with an angular micrometer disk reticule is required along with a 5 microliter water droplet syringe and a vial of clean water.

4.3.2.2 Procedure

4.3.2.2.1 Contact Angle - Using the 10X microscope, measure the contact angle of a 5 microliter water droplet placed on the coated slurper surface. Droplets shall be placed in at least twelve places. Record the location and contact angle of each droplet per Figure 3.

4.3.2.2.2 Time to Wet - At a minimum of twelve places, place a 5 microliter water droplet midway between slurper holes and measure the time to the nearest 0.1 seconds to wet to the slurper holes. Record the data per Figure 3.

Note: The contact angle is defined as the angle subtended between the coating surface and a line tangent to the water droplet at the point of contact with the surface such that the water droplet is included within the angle.



4.3.3 Pass - Fail Criteria

a. If the average contact angle is greater than 10 degrees, the cognizant SSD Materials Engineer shall disposition the suitability of the coating. If the angle is equal to or less than 10 degrees, the item is suitable for continued testing.

b. If the average time to wet is greater than 5 seconds, the cognizant SSD Materials Engineer shall disposition the suitability of the coating. If the time to wet is equal to or less than 5 seconds, the item is suitable for continued testing.

4.4 Proof Pressure and Leakage Test

4.4.1 Objective - The objective of the Proof Pressure and Leakage test is to verify the pressure and leakage integrity of the heat exchanger.

4.4.2 Test Setup

(a) The proof and leakage test shall be conducted on a bench within the SSD laboratory.

(b) The following instrumentation is required:

Instrument	Min. Range	Units	Type	Accuracy
Thermometer	32-100	°F	Hg	±1/2°F
Thermocouples	32-100	°F	Copper/ Const.	±1°F System
Pressure Gage	0-100	psig	Bourdon	±1%F.S.
Pressure Gage	0-5	psig	Bourdon	±1%F.S.

(c) Test equipment shall include the following:

Item	P/N	
Fitting Closures, Water	NPN-LLLHX-II-1	
Closures, Air	SV755539CT200	SV755508CT209-4
	SV755539CT201	SV755508CT209-5
	SV755508CT208-4	SV755503CT200
	SV755508CT208-5	SV755503CT201(3)

(d) Test setups are given in Figures 4, 5, and 6.

(e) Pressurant supply shall be Nitrogen per MIL-P-27401.

4.4.3 Procedure

(a) The heat exchanger is comprised of an air circuit and a primary and a redundant water circuit. These circuits may be tested in the most convenient sequence.

(b) Attach circuit closures.

(c) To test a circuit, attach regulated pressure supply to the circuit inlet with the outlet sealed. The other two circuits should be vented to ambient.

(d) Pressurize, slowly, to the pressure specified below. Close the supply shutoff and record the supply pressure. Record a second reading after ten minutes. If pressure decay is apparent, continue recording at 5 minute intervals for a total of 30 minutes max.

Note: Item and ambient temperatures shall be stable within $\pm 2F^{o}$ during the test.

(e) If the pressure cannot be maintained, attempt to locate the leak. Mark any leaks located and advise the cognizant Engineer. Weld repairs are acceptable.

(f) Repeat the procedure above for the other two circuits.

Heat Exchanger Circuit	Pressure (min.)	Units
Air	1.8	psid
Water (2)	90	psig

(g) Data shall be recorded for each run per Figure 7.

(h) Data corrections shall be required for variations in ambient and/or item temperature.

(i) A photograph of a typical test setup shall be taken prior to removal of the heat exchanger to the next test, on the first test only.

4.4.4 Pass - Fail Criteria

(a) There shall be no detectable leakage in ten minutes, after temperature corrections.

(b) There shall be no visible permanent deformation.

4.5 Performance

4.5.1. Objective - The objective of the performance test is to demonstrate that the heat exchanger is interchangeable with Shuttle CEI item 10 P/N 755504.

4.5.2 Test Setup

(a) The performance test shall be conducted within the Space System Department Laboratory.

(b) The required instrumentation is listed on Table I.

(c) The test shall be conducted on test rig 61 using an ancillary coolant water supply.

(d) The heat exchanger shall be set up and instrumented per Figures 8 and 9.

(e) Data shall be visually read and manually recorded on Log of Test Form, HSF175.1A. In addition, the serial number and calibration date of all instrumentation shall be recorded.

(f) Fluid cleanliness inherent to the test rigs shall be adequate.

(g) Test fluids shall be laboratory quality air and steam, provided by Rig 61 and the ancillary coolant water supply.

4.5.3 Procedure

(a) Mount the heat exchanger, make fluid connections (air and water) as shown on Figures 8 and 9, and instrument per Figures 8 and 9 and Table I. Fill the heat exchanger using the vacuum fill method with the pressure at 0.1 psia max before introducing water. During instrumentation, record the identification, serial number and calibration date of each instrument used. Photograph the test setup at some convenient time prior to completion of tests.

Note: Any instrument changes during test shall be recorded on the test data sheet.

(b) Measure the air, primary water and slurper pressure drops per Tables II, III, and VI recording the data per Figs. 10, 11, and 18. Change the coolant plumbing to the secondary cooling circuit and repeat the test points of Table III, recording the coolant pressure drops per Figure 12.

(c) The performance conditions to be tested are listed in Tables IV and V. The sequence of runs shall be that providing maximum test efficiency, except that all dry tests shall be completed before any wet tests are performed.

(d) The conditions for a test point shall be established per procedures inherent to rig operations. Record data every five minutes until conditions have stabilized and then continue recording at 5 minute intervals for a minimum of 5 additional readings. Conditions may be considered stabilized when inlet and outlet water and air temperature conditions do not vary more than 1.5°F for three consecutive readings. Record data per Figure 13.

(e) Proceed to next test point and repeat the above procedure until all test points per Tables IV and V have been tested and are accepted by Engineering. Then change the water connection to the secondary water loop and repeat wet performance test point No. 3.

(f) After the tests of Table IV have been completed, maintain the conditions of test point 2 of the Table IV and measure slurper pressure drops per Table VI and record data per Figure 19.

(g) Upon completion of heat balance calculations. per Figure 14, the cognizant Engineer shall indicate rejection or acceptance of the run by so noting and initialing on the data sheet. If a balance cannot be obtained, the operator shall repeat the run in the most efficient operating sequence.

(h) At completion of testing, the air and water circuits shall be dried by purging with dry air at 160-200°F for one hour. Air and water circuits shall be capped or covered with polyethylene film.

4.5.4 Pass - Fail Criteria - The following conditions shall be met for Test Point 2 of Table V:

Air Outlet Temperature	53°F max
Air Outlet Dew Point	53°F max
Air Pressure Drop	0.8 in. H_2O max
Coolant Pressure Drop	38.8 in. H_2O max

4.6 Vibration

4.6.1 Objective - The objective of the vibration test is to determine the ability of the laminate construction of the heat exchanger to withstand "shuttle" level vibration as defined herein.

4.6.2 Test Setup

(a) The test shall be conducted on the vibration test rig in the Hamilton Standard Space Systems Laboratory, or at an approved vendor facility.

(b) Vibration Test Tolerances - Plus or minus one db overall rms acceleration and plus or minus three db on acceleration spectral density (g^2/Hz) for the following:

Frequency Range	Maximum Effective Bandwidth
10 to 100 Hz	6 Hz
100 to 500 Hz	12 Hz
500 to 2000 Hz	24 Hz

Analysis sample time (T) shall equal or exceed 50/BW, where BW is the effective bandwidth of the filter utilized. For swept filter analysis, analyzer filter scan rate (SR) shall, (1) not exceed BW/T Hz/second when averaging is obtained using linear integration with an integration time of T; or (2) shall be BW/4RC when averaging is obtained by smoothing with an equivalent resistance capacitance (RC) low pass filter using a time constant RC equals T/2.

Peak and Notch Tolerance - Peaks and notches may not deviate more than ±3db from these limits between 500 and 2000Hz. The total frequency bandwidth of the peaks and notches deviating more than 1.5 db shall be less than 300 Hz. These tolerances are increased in roll off regions of the spectrum by ±0.1 db for every one db down from the maximum level specified. All db are in terms of power ratio. Peak and notches below 500 Hz may exceed the ±3 db tolerance by no more than 1.5 db and not exceed a bandwidth of 25 Hz.

Frequency Tolerance - The frequency shall be ±2%.

Exposure Time Tolerance (Minutes) - The exposure time shall be + 10% - 0%.

(c) Test Set-Up Sketch - In the space provided in HS Form 175.7, a sketch of the test item and fixture shall be made including the definition of the three orthogonal axes.

(d) Log Sheet - An operator's log sheet, Form HSF 175.1A, shall be provided. The log sheet shall contain run number, starting time of run, axis, mode (sinusoidal or random), scan rate, g's peak, and paragraph number of the test specification which delineates the vibration level requirements.

(e) Photographs - Photographs shall be taken which clearly illustrate the test item and set-up for each orthogonal axis. Polaroids are acceptable.

(f) Accelerometer Signals - The unfiltered signals from the installed accelerometers shall be recorded on magnetic tape for all tests. Response data will be provided upon specific written request from project engineer.

(g) Control Curve - A control curve shall be provided for each of the three orthogonal axis.

(h) Recording - The vibration control accelerometer signal and any response accelerometer signal shall be recorded (and identified by voice annotation) on magnetic tape for all tests. The tape recorder shall record these signals whenever power is applied to the shaker system. System calibration information (g's/volts, etc.) sufficient to allow analysis of the vibration signals subsequent to the test, shall also be recorded on the magnetic tape and any other applicable documentation. The magnetic tapes shall be maintained as part of the permanent vibration test records. The vibration control accelerometer(s) shall be located in accordance with the fixture investigation to ensure that the specified vibration is being applied to the the test specimen.

(i) Fixture Investigation - The test fixture and test item shall be subjected to a low level filtered sinusoidal vibration in accordance with standard Hamilton Standard practice to verify the fixture response characteristics in each of the three major orthogonal axes as specified below at 2 oct/min. sweep rate:

Frequency Range	Vibration Level
5-10 Hz	0.2 inch O.A
10-2000 Hz	$\pm$1.0 g pk.

The number of transducers required to conduct the fixture scan shall be specified by the cognizant structures engineer. From the results of the scan, the engineer shall select the adequate control location and record the selection. The sweep rate may be reduced near those frequencies where control becomes difficult to maintain in order to allow the servo to respond.

It shall not be necessary to repeat the fixture investigation for subsequent tests after the initial control location has been selected.

(j) Item Mounting - The test unit is to be fastened to the vibration test fixture TBD, which in turn will be secured to the vibration generator. The attachment of the test item to the vibration fixtures shall be in accordance with the requirements defined by the installation drawing (SVHS 755504). The three orthogonal axes are defined in Figure No. 15.

(k) Transducer Location

A. Install control accelerometer on the fixture at the fixture/item interface in accordance with the results of the figure investigation.

B. Install response accelerometers on the test unit per design engineering or cognizant test engineering instruction at time of test.

(l) Operation - The primary and secondary coolant loops of the test item shall be evacuated to 0.1 psia and back-filled with water prior to vibration. Each coolant loop shall be pressurized to 90^{+5}_{-0} psig. Once conditions have stabilized, shut water supply valves. Pressures shall be monitored during vibration testing. The evacuation and back-fill shall be accomplished using the test set-up in Figure 16. Record data before and after each axis vibration test on Log of Test per Figure 17.

Note: The capping of the ports may vary from Figure 16, although in each loop one end must be capped and the other end pressurized.

4.6.3 Test Procedure - For random vibration testing, a dynamically similar dummy shall be used in place of the test specimen, when possible, for pretest equalization(s). The final equalization prior to the test shall be accomplished using the test specimen and shall be conducted at the full specified random vibration level. The time expended during the final equalization shall be counted as part of the required test time for the random vibration test. The final equalization shall be verified by a narrow band analysis prior to initiation of the test, using effective bandwidths not exceeding those specified in paragraph 4.6.2 of this test plan. A narrow band spectral analysis shall be performed on the input control accelerometer signal once per hour during the test (analysis may be actually performed subsequent to test run) to demonstrate that the test specimen has been subjected to the specified random spectrum. All random spectral analysis shall be performed as x-y log-log plots of acceleration spectral density (g^2/Hz) versus frequency (Hz). The test shall be exposed to the spectrum defined by Figure 1 for 48 minutes in each of three orthogonal axes. The unit is to be filled and pressurized during all vibration testing.

4.6.4 Pass - Fail Criteria - The test item shall not exhibit damage and/or permanent deformation and the test item must successfully pass the subsequent leakage and performance tests.

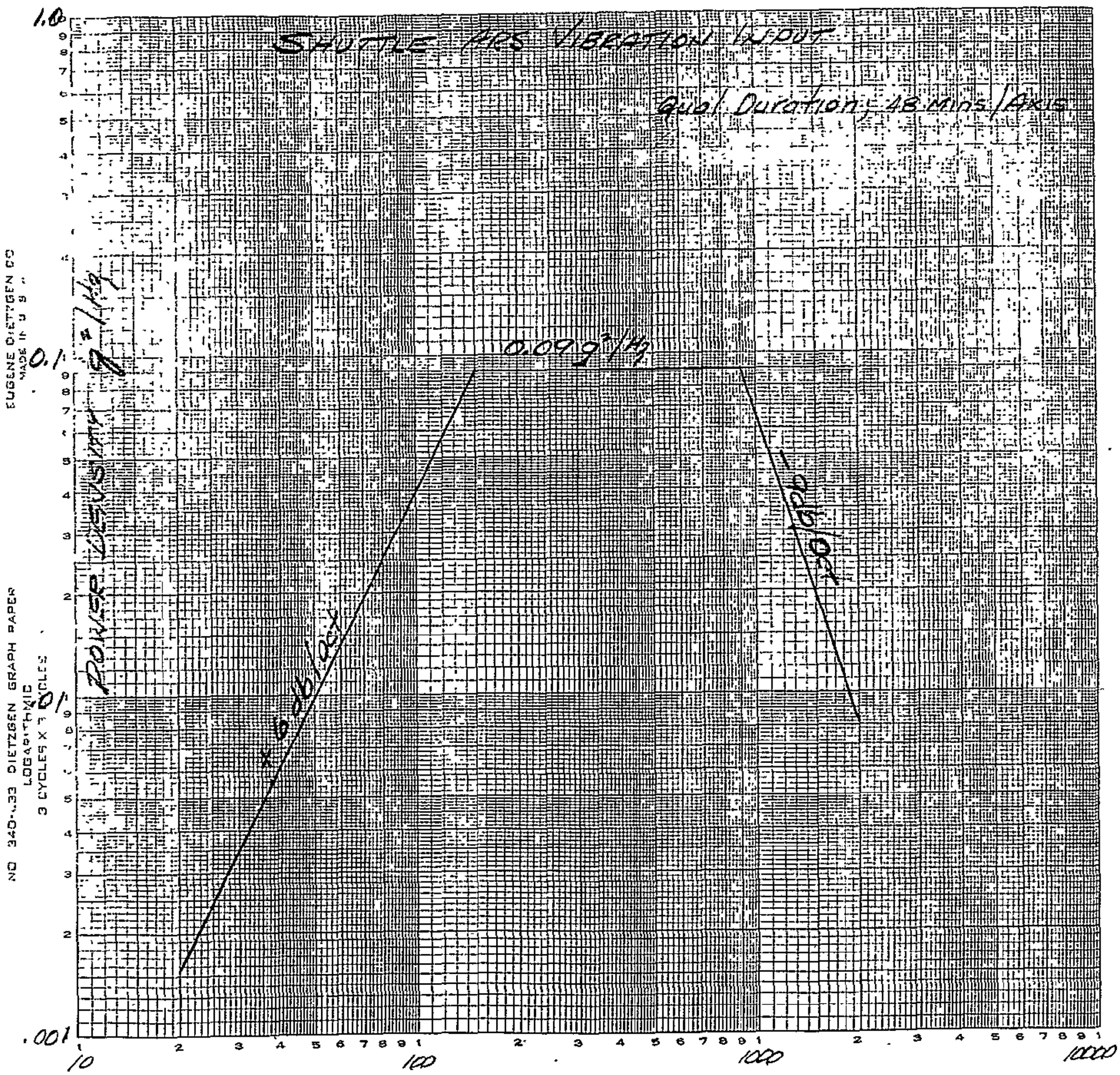

SHUTTLE ARS VIBRATION INPUT
Qual Duration; 48 Mins/Axis
0.09 g²/Hz
POWER DENSITY g²/Hz
+6db/oct
-10db/oct
1.0
0.1
.01
.001
10
100
1000
10000
FREQUENCY - Hz

FIG. 1

HSF 175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	Weight
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG ORDER NO.	
SHEET OF	
DATE	C43-002
TEST PLAN NO.	
MODEL NO.	
PART NO	
SERIAL NO.	
OPERATORS	

	First Dry Cycle	Second Dry Cycle	Third Dry Cycle
Start Time			
End Time			
Temp. at Start			
Temp. at End			
Vacuum at Start			
Vacuum at End			
Time at Weighing			
Weight			

REMARKS

FIGURE 2

HSF 175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

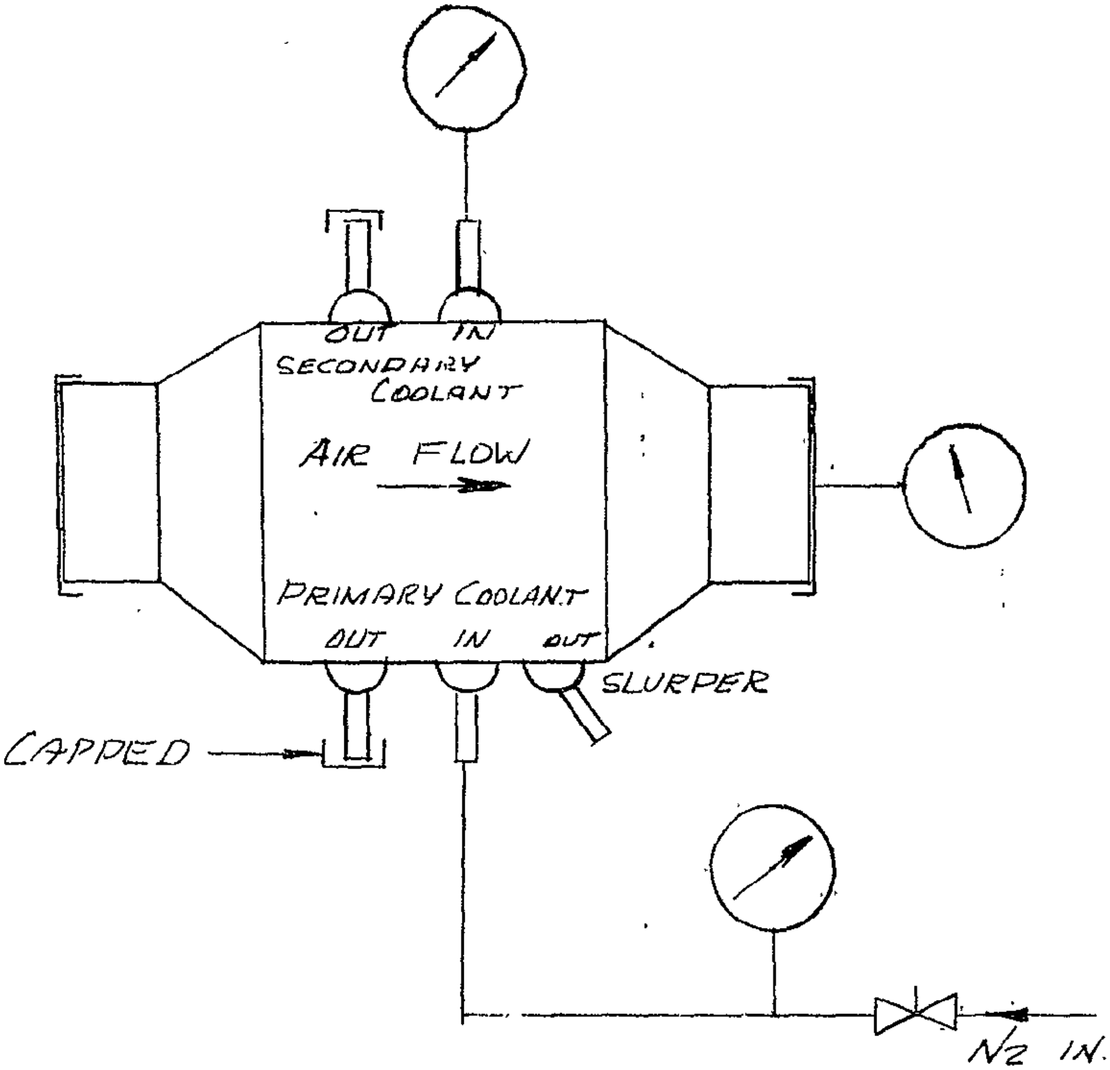
LOG OF TEST

TYPE OF TEST: Coating Characteristics	SHEET OF	DATE C43-002
TEST ENGINEER	TEST PLAN NO	
NAME OF RIG	MODEL NO	
PROJECT & ENG ORDER NO.	PART NO.	
	SERIAL NO.	
	OPERATORS	

Test Point	Contact Angle θ o	Time to Wet secs
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
	Ave. Contact Angle =	Ave. Time to Wet =

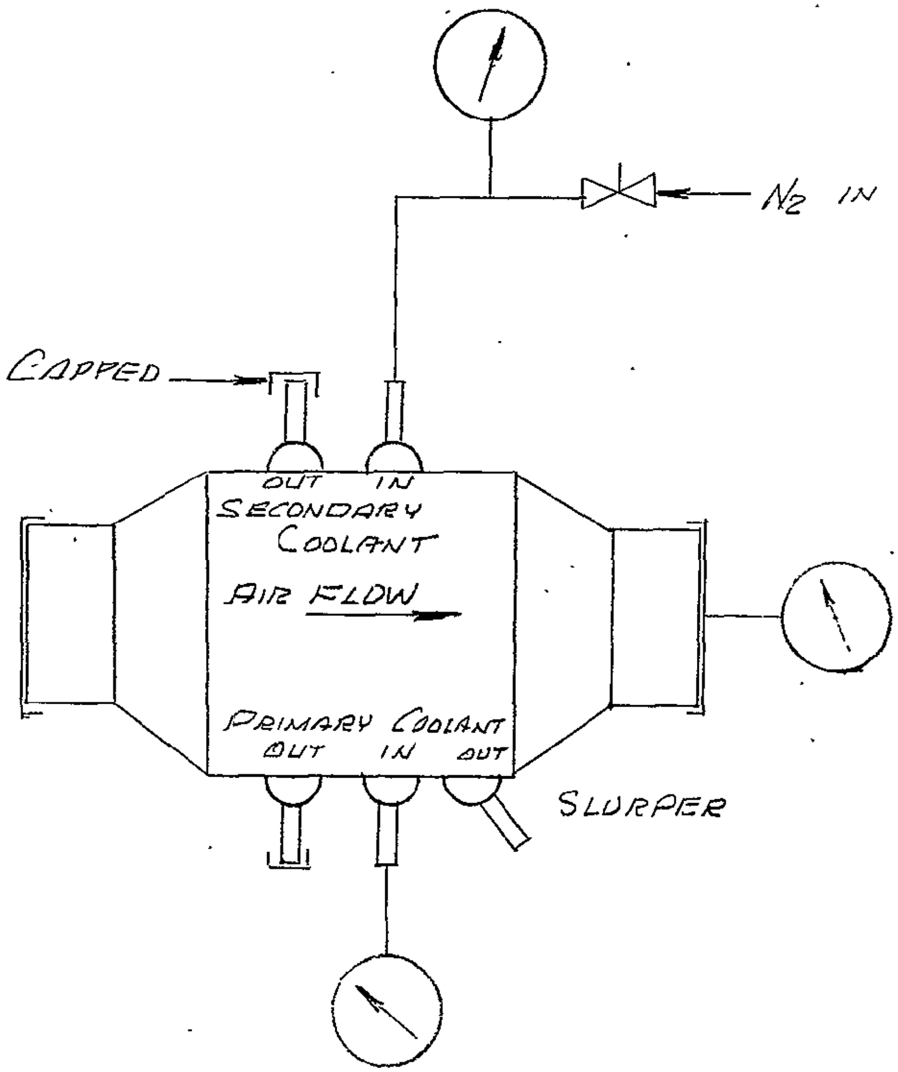
REMARKS

FIGURE 3



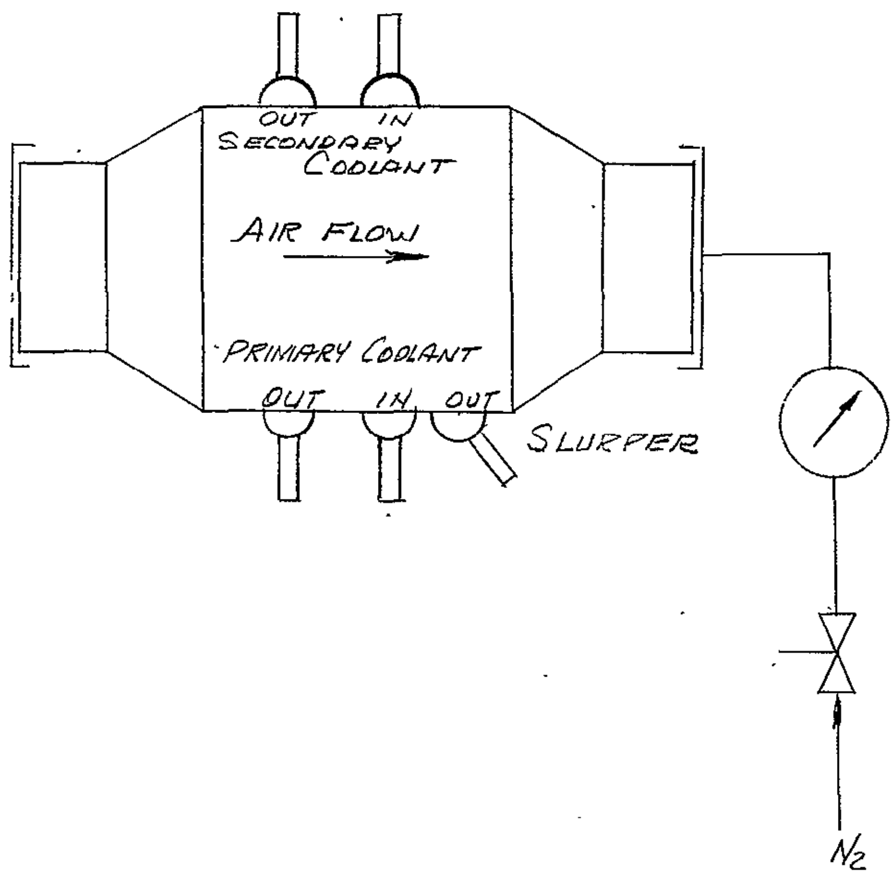
PRIMARY COOLANT LOOP PROOF AND LEAKAGE

FIGURE 4



SECONDARY LOOP PROOF AND LEAKAGE

FIGURE 5



AIR LOOP PROOF AND LEAKAGE

FIGURE 6

HSF 179 1A 1/56

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Proof and Leakage

TEST ENGINEER

NAME OF RIG

PROJECT & ENG ORDER NO.

SHEET OF

DATE C43-002

TEST PLAN NO.

MODEL NO.

PART NO

SERIAL NO

OPERATORS

	Primary Loop	Secondary Loop	Air Loop
Barometric Pressure, in Hg			
Ambient Temperature, °F			
Initial Pressure Psia			
Item Temperature °F			
Pressure in 10 mins, psia			
15			
20			
25			
30			
Temperature in 10 mins, °F			
15			
20			
25			
30			

REMARKS

FIGURE 7

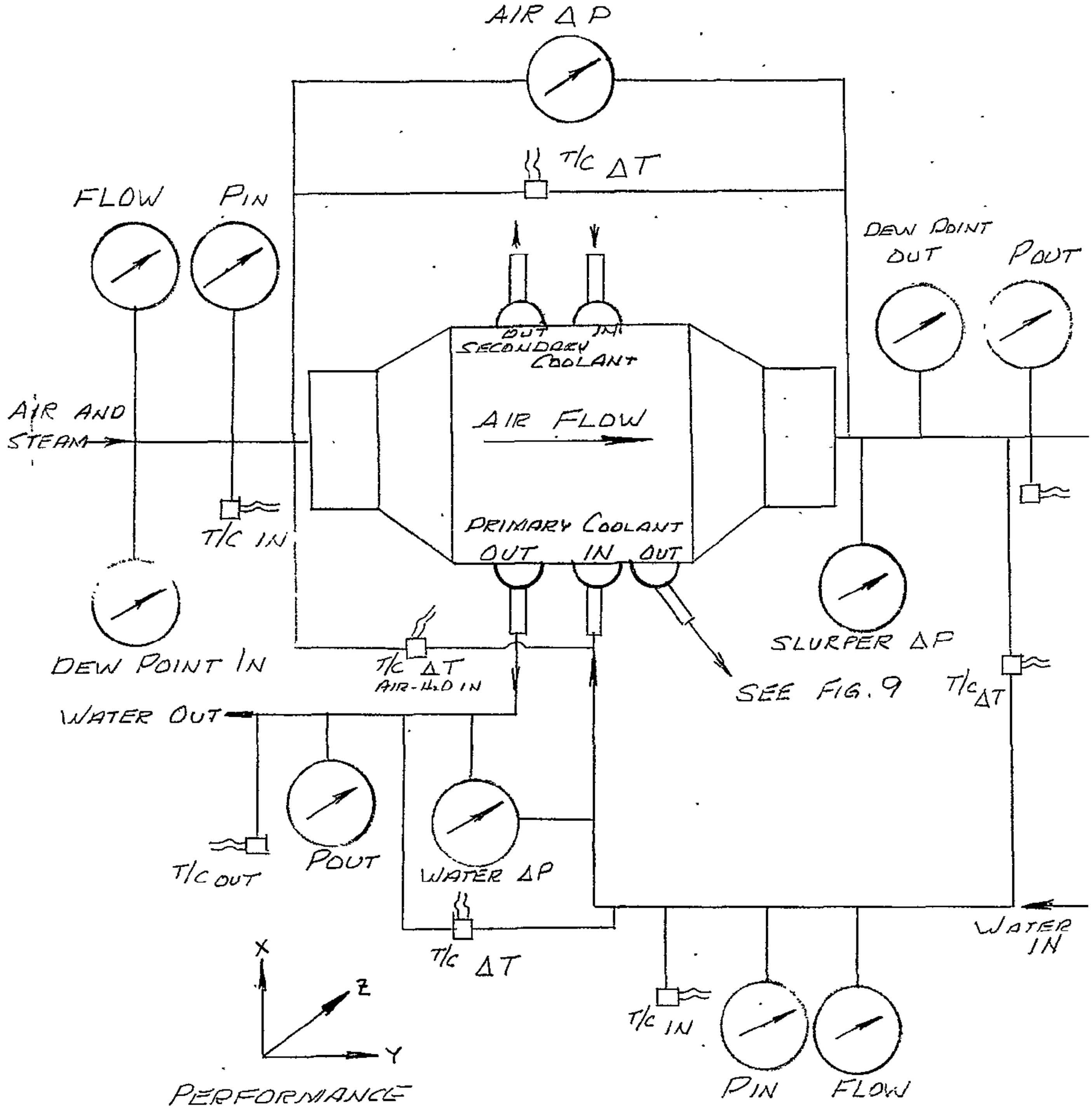
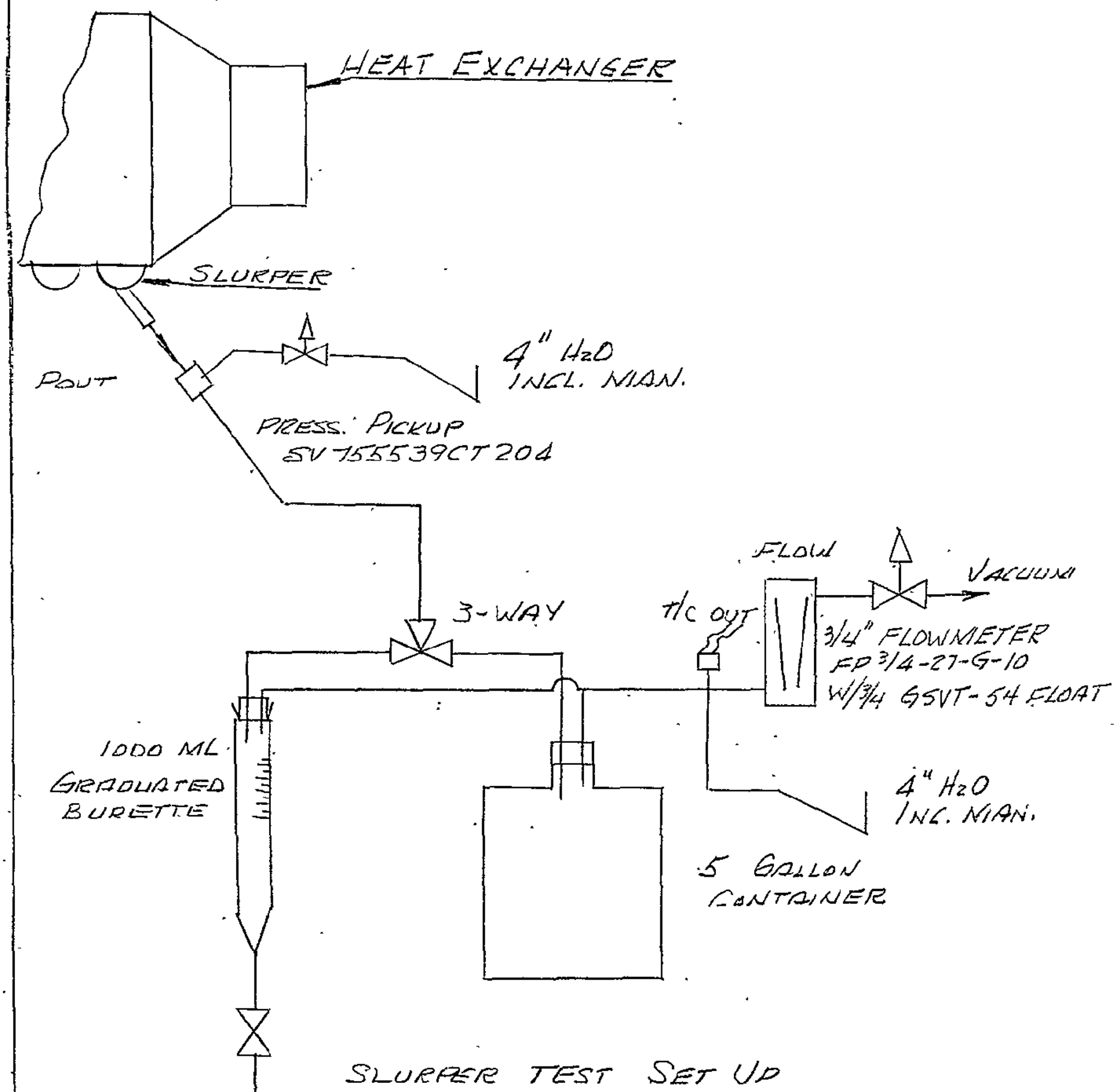

AIR ΔP
T/C ΔT
FLOW
PIN
DEW POINT OUT
POUT
OUT
IN
SECONDARY COOLANT
AIR AND STEAM
AIR FLOW
T/C IN
PRIMARY COOLANT
OUT
IN
OUT
DEW POINT IN
T/C ΔT AIR-H2O IN
SLURPER ΔP
SEE FIG. 9
T/C ΔT
WATER OUT
T/C OUT
POUT
WATER ΔP
T/C ΔT
WATER IN
X
Z
Y
T/C IN
PERFORMANCE
PIN
FLOW

FIGURE 8



SLURPER TEST SET UP

FIGURE 9

HSF 175 (A 1/66)

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Air Side Pressure Drop

TEST ENGINEER

NAME OF RIG

PROJECT & ENG ORDER NO.

SHEET OF

DATE C43-002

TEST PLAN NO

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

Time		Test Point		Tin	Tout	Pin		Dew Point in	Dew Point out	Air Flow		ΔP		Pair Out								
				°F		psia		°F		lb/Hr		in H_2O		psia								

REMARKS

FIGURE 10

PSF 175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Primary Coolant ΔP
TEST ENGINEER
NAME OF RIG
PROJECT & ENG. ORDER NO.

SHEET OF DATE C43-002
TEST PLAN NO
MODEL NO.
PART NO
SERIAL NO.
OPERATORS

Time		Test Point		Tin ^oF		Pin psig		Flow lb/Hr		ΔP in H_2O												

REMARKS

FIGURE 11

PSF 175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Secondary Loop ΔP	SHEET OF	DATE C43-002
TEST ENGINEER	TEST PLAN NO.	
NAME OF RIG	MODEL NO.	
PROJECT & ENG. ORDER NO.	PART NO	
	SERIAL NO.	
	OPERATORS	

Time	Test Point		Tin °F		Pin psig		Flow lb/Hr		ΔP in H_2O													

REMARKS:

FIGURE 12

PSF 175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Performance		SHEET OF	DATE C43-002
TEST ENGINEER		TEST PLAN NO.	
NAME OF RIG		MODEL NO.	
		PART NO	
		SERIAL NO.	
PROJECT & ENG. ORDER NO.		OPERATORS	

Run	Time	H_2O Circuit		H_2O Flow lb/Hr	H_2O Flow %	H_2O Temp in °F	H_2O ΔT °F	H_2O Press in psig	H_2O Press Out psig	Slurper ΔP H_2O	H_2O ΔP psid	Air Flow lb/Hr	Air Temp in °F	Air Temp out °F	Air ΔT °F	Air Press in in H_2O	Air Press out in H_2O	Air ΔP in H_2O	Air Dew Point in °F	Air Dew point out °F	Air H_2O ΔT Out T in °F	Air In H_2O In ΔT °F

REMARKS:

FIGURE 13

TEST DATA VERIFICATION - HEAT BALANCE

Step	Item	From	Units	CONDITIONS 1	2	3	4	5	6	7	8	9	10	11	12
A	ΔTa	log	F°												
B	$q_{air\ sens}$	A x 0.24	Btu/lb d.a												
C	Inlet Vapor	W/7000	lb H_2O/lb/d.a.												
D	h Vapor in	Steam Tab.	Btu/lb H_2O												
E	Qv_{in}	C x D	Btu/lb d.a.												
F	Outlet Vapor	W_L/7000	lb H_2O/lb d.a.												
G	h Vapor out	Steam Tab	Btu/lb H_2O												
H	qv out	F x Q	Btu/lb d.a.												
J	q v sens	E-H	Btu/lb d.a.												
K	ΔW_u	C-F	lb H_2O/lb d.a.												
L	h l	Steam Tab	Btu/lb H_2O												
M	q v lat.	K x L	Btu/lb d.a.												
N	qtotal	B+J+M	Btu/lb d.a.												
O	ma	log	lb d.a. hr												

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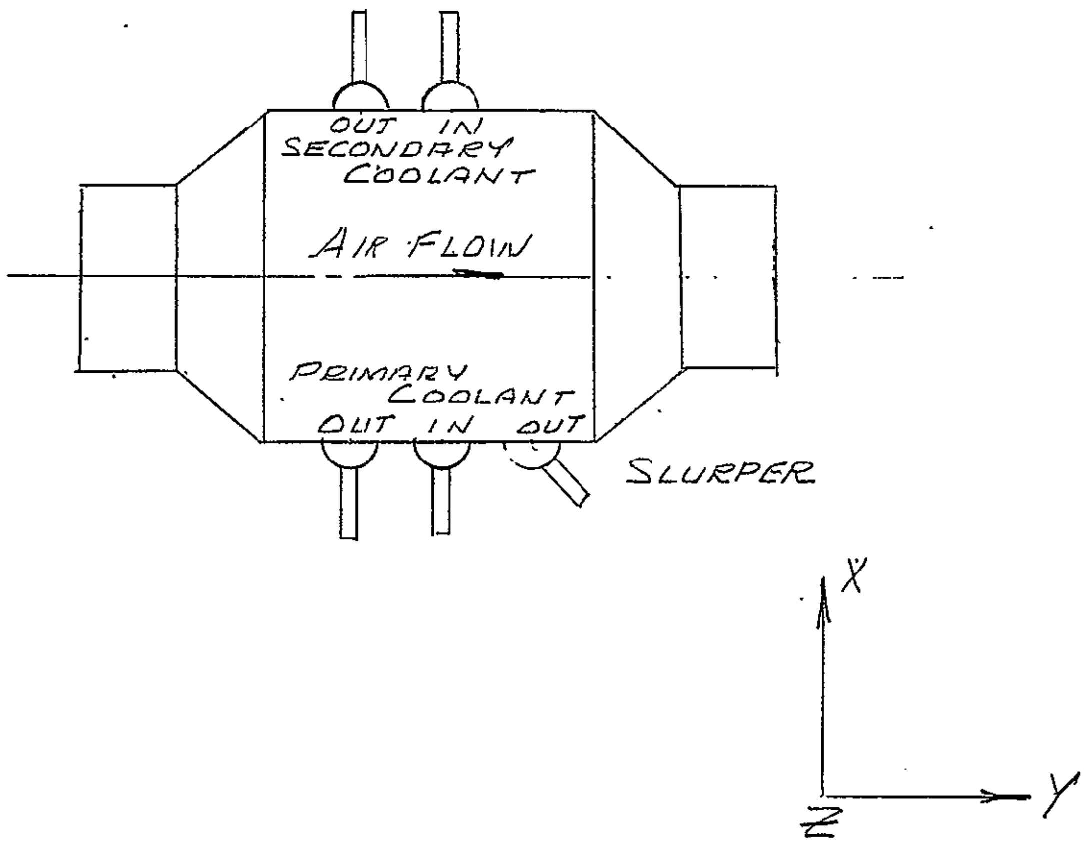
Page 23
C43-002 A

FIGURE 14

Step	Item	From	Units	1	2	3	4	5	6	7	8	9	10	11	12
P	Q air	N x O	Btu/hr												
Q	m_{H_2O}	log	lb H_2O/hr												
R	ΔTi	log	F°												
S	Q_{H_2O}	(1.0) x Q x R	Btu/hr												
T	Balance	$\frac{P-S}{S}$ x 100 (0±10%)	%												

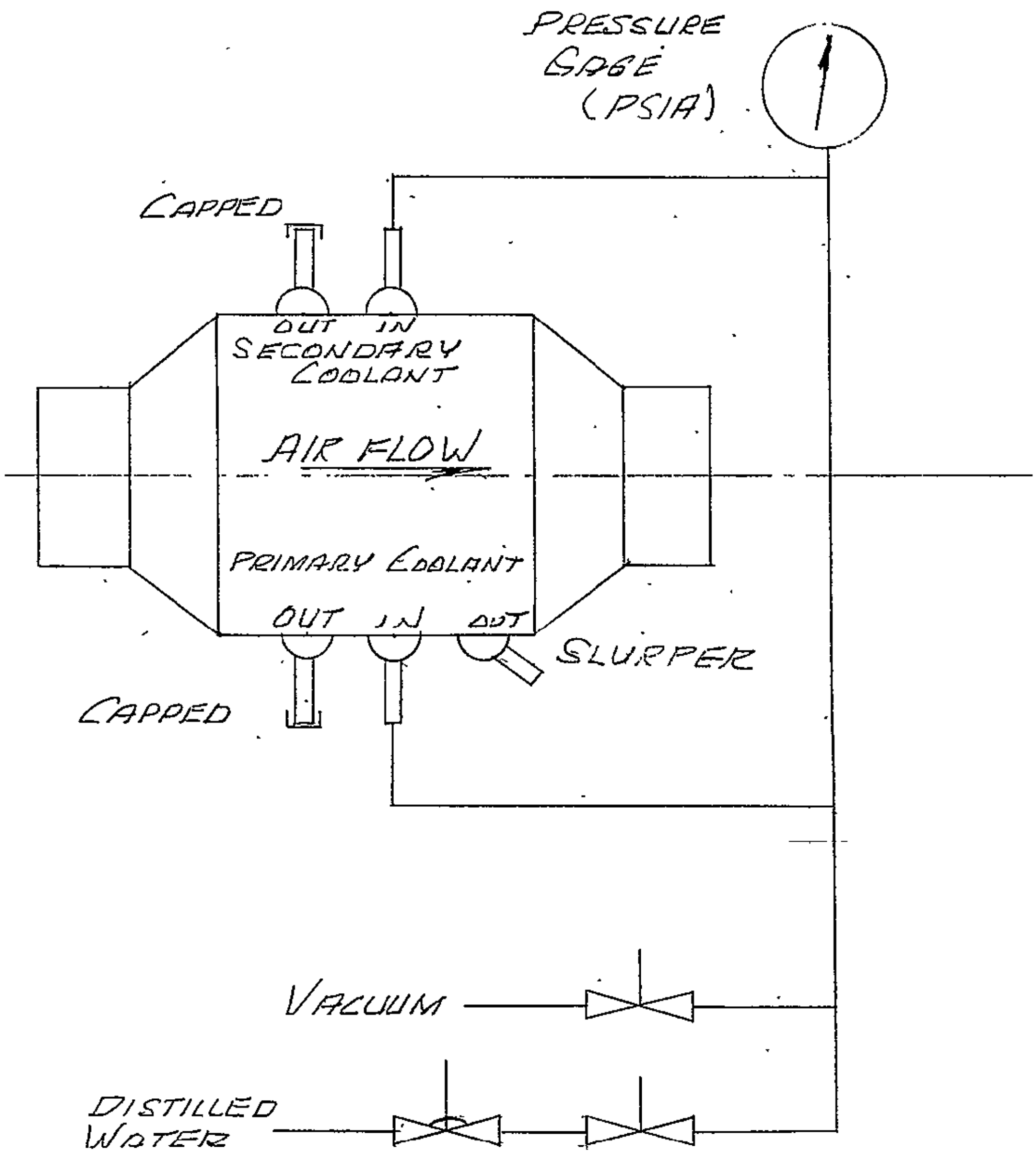
FIGURE 14 (Cont'd)

X AXIS - USE FIXTURE TBD
Y AXIS - USE FIXTURE TBD
Z AXIS - USE FIXTURE TBD



VIBRATION AXIS

FIGURE 15



VIBRATION OPERATION

FIGURE 16

HSF 175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

UA

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Vibration

TEST ENGINEER

NAME OF RIG

PROJECT & ENG. ORDER NO

SHEET OF

DATE C43-002

TEST PLAN NO

MODEL NO.

PART NO

SERIAL NO.

OPERATORS

Time	Para No		Run No	Axis	Scan	Mode	Scan Rate	g's Peak			Primary Coolant					Secondary Coolant						
											Pin Start psig		Pin Stop psig			Pin Start psig		Pin Stop psig				

REMARKS

FIGURE 17

HSF 178 (A) 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST	SLURPER ΔP W/O AIR FLOW
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG ORDER NO.	
SHEET OF	
DATE	C43-002
TEST PLAN NO	
MODEL NO	
PART NO	
SERIAL NO.	
OPERATORS	

Time		Test Point		Tin $^\circ F$		Pin Psia		Flow lbs/Hr		ΔP "H_2O												
		1																				
		2																				
		3																				
		4																				

REMARKS

FIGURE 18

HSP-175 (A 1/66)

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Slurper ΔP with Air Flow
TEST ENGINEER
NAME OF RIG
PROJECT & ENG ORDER NO.

SHEET OF DATE C43-002
TEST PLAN NO
MODEL NO.
PART NO
SERIAL NO.
OPERATORS

Time		Test Point		Tin	Pin	Air DPin	Flow	ΔP	Pout			Slurper Tin	Pin	Flow	ΔP							
				°F	Psia	°F	lbs/Hr	"H_2O	Psia			°F	Psia	lbs/Hr	"H_2O							

REMARKS

FIGURE 19

INSTRUMENTATION

Item	Range	Accuracy
Inlet Water Flow, $\mathring{M}_{H_2O}$	160-1600lbs/Hr Min	2% of reading
Inlet Water Temp., T_{H_2O} in	0-100°F	$\pm 1°F$
Inlet Water Press., P_{H_2O} in	0-60 psia	± 0.1 psi
Inlet Air Flow, $\mathring{M}$ air	0-1500lbs/Hr Min	2% of reading
Inlet Air Temp. T air in	35-160°F	$\pm 1°F$
Inlet Air Dew Point, TDP in	0-100°F	$\pm 2°F$
Inlet Air Pressure, P air in	0-20 psia	± 0.1 psi
Water Pressure Drop, ΔP H_2O	0-60 in H_2O	± 0.1 in H_2O
Air Pressure Drop, ΔP air	0-5 in H_2O	± 0.1 in H_2O
Water Temp. Rise, ΔT H_2O	0-100°F	$\pm 0.5°F$
Air Temp. Drop, ΔT air	0-100°F	$\pm 0.5°F$
Outlet Air Temp, T air out	35-160°F	$\pm 1.0°F$
Outlet Air Dew Point, TDP out	0-100	$\pm 2.0°F$
Inlet Temp Diff., ΔT air in H_2O	0-100	$\pm 0.5°F$
Inlet Temp Diff., ΔT air out H_2O in	0-100	$\pm 0.5°F$

TABLE I

AIR PRESSURE DROP CONDITIONS

TEST CONDITIONS	UNITS	TEST POINTS 1	2	3	4	Tolerance
AIR INLET TEMPERATURE	°F	80	80	104	80	±1
AIR INLET PRESSURE	psia	14.7	14.7	14.7	14.7	±1
AIR INLET DEWPOINT	°F	<30	<30	<30	<30	–
AIR FLOW	Lbs/Hr	700	1000	1366	1600	±5

TABLE II

COOLANT PRESSURE DROP CONDITIONS

TEST CONDITIONS	UNITS	TEST POINTS 1	2	3	4	Tolerance
AIR INLET TEMPERATURE		—	—	—	—	
AIR INLET PRESSURE		—	—	—	—	
AIR INLET DEWPOINT		—	—	—	—	
AIR FLOW		—	—	—	—	
COOLANT INLET TEMPERATURE	°F	45	45	45	45	±1
COOLANT INLET PRESSURE	psig	25	25	25	25	±1
COOLANT FLOW	Lbs/Hr	600	800	1000	1200	±5

TABLE III

DRY PERFORMANCE CONDITIONS

TEST CONDITIONS	UNITS	TEST POINTS 1	2	3	4	Tolerance
AIR INLET TEMPERATURE	°F	79.8	85.3	104.0	—	±1
AIR INLET PRESSURE	psia	14.7	14.7	14.7	—	±1
AIR INLET DEWPOINT	°F	<30	<30	<30	—	±1
AIRFLOW	Lbs/Hr	461	1411	1366	—	±5
SLURPER AIR FLOW	Lbs/Hr	36	36	36	—	±1
COOLANT INLET TEMPERATURE	°F	42	49	43.5	—	±1
COOLANT INLET PRESSURE	psig	25	25	25	—	±1
COOLANT FLOW	Lbs/Hr	460	1025	1009	—	±5

TABLE: IV

WET PERFORMANCE CONDITIONS

TEST CONDITIONS	UNITS	TEST POINTS 1	2	3	4	Tolerance
AIR INLET TEMPERATURE	°F	79.8	85.3	104.0	—	±1
AIR INLET PRESSURE	psia	14.7	14.7	14.7	—	±1
AIR INLET DEWPOINT	°F	53.5	55.5	57.6	—	±0.1
AIR FLOW	Lbs/Hr	461	1411	1366	—	±5
SLURPER AIR FLOW	Lbs/Hr	36	36	36	—	±1
COOLANT INLET TEMPERATURE	°F	42	49	43.5		±0.1
COOLANT INLET PRESSURE	psig	25	25	25	—	±1
COOLANT FLOW	Lbs/Hr	460	1025	1009	—	±5

TABLE V

SLURPER ΔP WITHOUT AIR FLOW

TEST CONDITIONS.	UNITS	TEST POINTS				Tolerance
		1	2	3	4	
SLURPER INLET AIR TEMP	°F	50	50	50	50	
SLURPER INLET AIR PRESS.	PSIA	14.7	14.7	14.7	14.7	
SLURPER AIR FLOW	LBS/HR	20	30	40	50	

TABLE VI

APPENDIX C

TEST LOGS

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: WEIGHT
TEST ENGINEER: E. MOORE
NAME OF RIG: 12
PROJECT & ENG. ORDER NO.: C43-400-001B

SHEET 1 OF 1 DATE 5-5-76
TEST PLAN NO. C 43-002
MODEL NO LONG LIFE HUM H.X.
PART NO SVSK 90348-1
SERIAL NO
OPERATORS [redacted]

	FIRST DRY CYCLE	SECOND DRY CYCLE	THIRD DRY CYCLE
START TIME	2030 HR	1230 hr.	
END TIME	2300 HR	1330 hr.	
TEMP. AT START	138 °F	103 °F	
TEMP AT END	144 °F	135.0 °F	
VACUUM AT START	.5 mm	0.6 MM	
VACUUM AT END	.3 mm	0.5 MM	
TIME AT WEIGHING	5/6/76 11:20	14:30	
WEIGHT	19.26	19.25	

SLAHTOSKY

REMARKS:

22521

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

HSF 175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Coating Characteristics	SHEET OF	DATE C43-002	
TEST ENGINEER	TEST PLAN NO.		
	MODEL NO.		
NAME OF RIG	PART NO.		
	SERIAL NO.		
PROJECT & ENG. ORDER NO.	OPERATORS		

Test Point		Contact Angle ∡ °		Time to Wet secs		
1	Center	~30°		>30 sec		(left side <10° & 1 sec) (R.S. ~30° 25 sec)
2	Center	~30°		>30 sec		(L.S. <10° & 2 Sec) (R.S. ~30° >30 sec)
3	Center	~30°		>30 sec		(L.S. <10° & 1 sec) (R.S. ~30° >30 sec)
4	Center	<10°	✓	1 sec	✓	(LS & RS OK)
5	Center	20-30°		15 sec		(LS <10° 1 sec) (R.S. ~30° >30 sec)
6	"	20-30°		>30 sec		(LS <10° 1 sec) (RS. ~30° >30 sec)
7	"	<10°	✓	1 sec	✓	(LS & RS OK)
8	"	20-30°		>30 sec		(L.S. <10° 2 sec) (R.S. ~30° >30 sec)
9	"	<10°	✓	1 sec	✓	(LS >30° >30 sec) (R.S. ~10° 5 sec)
10	"	~10°		5 sec	✓	(LS ~10° 2 sec) (R.S. ~20° 25 sec)
11	"	<10°	✓	1 sec	✓	(LS <10° 1 sec) (R.S. >30° >30 sec)
12	"	<10°		1 sec	✓	(LS 20-30° 6 sec) (R.S. 20-30° 23 sec)

Ave. Contact Angle =

Ave. Time to Wet =

REMARKS.

R. Ruby 5/10/76

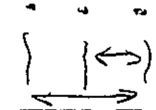


FIGURE 3

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: PROOF + LKG
TEST ENGINEER: E.K. MOORE
NAME OF RIG: 64
PROJECT & ENG. ORDER NO: C43-400-001B

SHEET 1 OF   DATE 5-10-76
TEST PLAN NO. C43-003 A
MODEL NO LLL HX-II
PART NO. SVSK 90348-1
SERIAL NO.
OPERATORS SLAHTOSKY

	Primary Loop	Secondary Loop	5-11-76 Air Loop
BAROMETRIC PRESS., IN. HG.	29.89	29.86	29.76
AMB TEMP, °F	68.8	69.0	69.0
INITIAL PRESS PSIG	90.0	90.0	1.8
ITEM TEMP. °F	70.0	70.0	68.0
PRESS IN 10 MIN. PSIG	89.8	90.0	1.42
" " 15 MIN "	89.6	89.9	1.28
" " 20 MIN. "	89.5	89.8	1.13
" " 25 MIN. "	89.4	89.7	1.05
" " 30 MIN. "	89.3	89.6	.90
TEMP IN 10 MIN. °F	70.0 °F	70.0 °F	68.0
" " 15 " "	80.0	70.0°	68.0
" " 20 " "	70.0	70.0°	68.0
" " 25 " "	70.0	70.0	68.0
" " 30 " "	70.0	70.0°	68.0

REMARKS

12205

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: MEASURE LKG.

TEST ENGINEER: E.K. MOORE

NAME OF RIG: 64

PROJECT & ENG. ORDER NO.: C43-400-001B

SHEET 1 OF   DATE 5-10-76

TEST PLAN NO C43-002A

MODEL NO LLL HX II

PART NO. SVSK 90348-1

SERIAL NO.

OPERATORS SLAHTOSKY

# RUN	PIN PSIG	TEMP °F	
1	100.	70.0°	PRESS TO 100.0 PSIG, VALVE "A" CLOSED, "B" OPEN
			CLOSE VALVE "C", OPE VALVE "A". PRESS. DROPED TO 48.0 PSIG
	53.0	70.0°	+ UP TO 53.0
2	100.	70.0°	SAME AS ABOVE
	53.4	70.0°	
3	100.	70.0°	SAME AS ABOVE
	53.1	70.0°	

REMARKS:

22522

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: AIR SIDE PRESS DROP
TEST ENGINEER: E.K. MOORE
NAME OF RIG: 61
PROJECT & ENG ORDER NO.: C43-400-001B

SHEET 1 OF 2 DATE 5-14-76
TEST PLAN NO. C43-002
MODEL NO. LLLHX-II
PART NO SVSK 90348-1
SERIAL NO.
OPERATORS Kulle

TIME	TEST POINT	T IN #1 °F	T OUT #2 °F	P IN "H2O	ΔP "H2O	D.P IN °F	D.P. OUT °F	AIR FLOW lb/HR
2210	1	79.9	79.9	.35	.22	27.5	27.5	699.6
2215	1	79.8	79.9	.35	.22	26.5	26.5	699.6
2220	1	79.8	79.9	.35	.22	26.0	26.0	699.6
2225	1	79.8	79.9	.35	.22	26.0	26.0	699.6
2230	1	79.8	79.9	.35	.22	26.0	26.0	699.6
2235	1	79.7	79.8	.35	.22	26.0	26.0	699.6
2300	2	80.6	80.8	.67	.40	20.0	20.0	999.6
2305	2	80.7	80.8	.67	.40	19.5	19.5	999.6
2310	2	80.7	80.8	.67	.40	18.5	18.5	999.6
2315	2	80.6	80.7	.67	.39	17.5	17.5	999.6
2320	2	80.6	80.7	.67	.39	17.0	17.0	999.6
2325	2	80.6	80.7	.67	.40	16.0	16.0	999.6
2330	2	80.6	80.7	.67	.40	16.0	16.0	999.6

WITNESSED [signature] 5-14-76

REMARKS
FIG #10

22762

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: Air Side Press Drop
TEST ENGINEER: E. K. Moore
NAME OF RIG: 61
PROJECT & ENG. ORDER NO.: C 43-400-001B

SHEET 2 OF 2 DATE 5-17-76
TEST PLAN NO C43-002
MODEL NO. LLLHX-II
PART NO. SVSK 90348-1
SERIAL NO.
OPERATORS KULLE

Time	Test Point No.	Tin #1 °F	Tout #2 °F	Pin "H2O	ΔP "H2O	D.P. In °F	D.P. Out °F	Air Flow lb/HR
1945	3	103.9	103.5	1.22	.68	29.5	21.0	1365.6
1950	3	104.0	103.6	1.22	.68	29.0	21.0	1365.6
1955	3	104.1	103.6	1.22	.68	29.5	21.5	1365.6
2000	3	104.1	103.6	1.22	.68	29.5	21.5	1365.6
2005	3	104.1	103.6	1.22	.68	29.5	21.5	1365.6
2010	3	104.1	103.6	1.22	.68	29.5	21.5	1365.6
2125	4	80.5	80.8	1.54	.82	11.0	8.5	1600.2
2130	4	80.4	80.8	1.54	.82	11.0	8.5	1600.2
2135	4	80.4	80.8	1.54	.82	11.0	8.5	1600.2
2140	4	80.4	80.7	1.54	.82	11.0	8.5	1600.2
2145	4	80.4	80.7	1.54	.82	11.0	8.5	1600.2
2150	4	80.3	80.7	1.54	.82	11.0	8.5	1600.2

WITNESSED [illegible] 5-17-76

REMARKS:

22595

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST SECONDARY Coolant Pressure Drop
TEST ENGINEER E. K. Moore
NAME OF RIG 61 and 61A
PROJECT & ENG. ORDER NO C43-400-001B

SHEET 1 OF 2 DATE 5-19-76
TEST PLAN NO. C43-002
MODEL NO. LLL HX-II
PART NO SVSK 90348-1
SERIAL NO.
OPERATORS KJ/JE
Secondary H_2O Loop

Time	Test Point No	Tin °F	Pin Psig	Flow lb/hr	ΔP "H_2O	Flow CPS	K Factor
1830	1	45.1	25.0	599.3	26.0	581	1.0315
1835	1	45.0	25.0	599.3	26.0	581	1.0315
1840	1	44.9	25.0	599.3	26.0	581	1.0315
1845	1	44.9	25.0	599.3	26.0	581	1.0315
1850	1	44.9	25.0	599.3	26.0	581	1.0315
1855	1	45.0	25.0	599.3	26.0	581	1.0315
2035	2	44.6	24.7	800.4	43.0	775	1.0328
2040	2	44.6	24.7	800.4	43.0	775	1.0328
2045	2	44.5	24.7	800.4	43.0	775	1.0328
2050	2	44.5	24.7	800.4	43.0	775	1.0328
2055	2	44.6	24.7	800.4	43.0	775	1.0328
2100	2	44.6	24.7	800.4	43.0	775	1.0328
2200	3	44.5	25.1	1000.3	62.5	967	1.0345
2205	3	44.6	25.1	1000.3	62.5	967	1.0345
2210	3	44.6	25.1	1000.3	62.5	967	1.0345
2215	3	44.6	25.1	1000.3	62.5	967	1.0345
2220	3	44.6	25.1	1000.3	62.5	967	1.0345
2225	3	44.6	25.1	1000.3	62.5	967	1.0345

REMARKS:

22543

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST SECONDARY Coolant Pressure Drop
TEST ENGINEER E.K. Moore
NAME OF RIG 61 and 61A
PROJECT & ENG. ORDER NO. C43-400-001B

SHEET 2 OF 2 DATE 5-19-76
TEST PLAN NO. C43-002
MODEL NO. LLLHX-II
PART NO SVSK 90348-1
SERIAL NO.
OPERATORS Kulle
Secondary H2O loop

Time	Test Point No	Tin °F	Pin Psig	Flow Lb/Hr	ΔP "H2O	Flow CPS	K Factor
2330	4	45.1	25.8	1201.41	85.5	1160	1.0357
2335	4	45.1	25.8	1201.41	85.5	1160	1.0357
2340	4	45.1	25.8	1201.41	85.5	1160	1.0357
2345	4	45.1	25.8	1201.41	85.5	1160	1.0357
2350	4	45.1	25.8	1201.41	85.5	1160	1.0357
2355	4	45.1	25.8	1201.41	85.5	1160	1.0357

REMARKS:

22547

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST SECONDARY Coolant Pressure Drop
TEST ENGINEER E. K. Moore
NAME OF RIG 61 and 61A
PROJECT & ENG. ORDER NO C 43-400-001 B

SHEET 1 OF 1 DATE 5-20-76
TEST PLAN NO. C 43-002
MODEL NO. LLLHX-II
PART NO. SVSK 90348-1
SERIAL NO.
OPERATORS Kulle
Secondary H_2O Loop

Time	Test Point No.	T_{in} °F	P_{in} PSIG	Flow #/Hr	ΔP "H_2O	Flow CPS	K Factor
1830	4	44.9	60	1201.4	85.5	1160	1.0357
1835	4	44.8	60	1201.4	85.5	1160	1.0357
1840	4	44.8	60	1201.4	85.5	1160	1.0357
1845	4	44.8	60	1201.4	85.5	1160	1.0357
1850	4	44.9	60	1201.4	85.5	1160	1.0357
1855	4	44.9	60	1201.4	85.5	1160	1.0357

REMARKS:

22497

HSF 175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

WINDSOR LOCKS, CONNECTICUT 06096

UA

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Primary Coolant Pressure Drop

TEST ENGINEER E.K. Moore

NAME OF RIG 61 and 61A

PROJECT & ENG. ORDER NO. C43-408-0013

SHEET 1 OF 2 DATE 5-18-76

TEST PLAN NO C43-002

MODEL NO. LLHX-II

PART NO SVSK 90348-1

SERIAL NO.

OPERATORS Kulle

Primary H_2O Loop

Time	Test Point No.	Tin °F	Pin Psig	Flow lb/Hr	ΔP "H_2O	Flow CPS	K Factor
1840	1	45.2	24.9	599.3	25.5	581	1.0315
1845	1	45.3	24.9	599.3	25.5	581	1.0315
1850	1	45.2	24.9	599.3	25.5	581	1.0315
1855	1	45.2	24.9	599.3	25.5	581	1.0315
1900	1	45.3	24.9	599.3	25.5	581	1.0315
1905	1	45.2	24.9	599.3	25.5	581	1.0315
2020	2	45.6	25	800.4	42.5	775	1.0328
2025	2	45.6	25	800.4	42.5	775	1.0328
2030	2	45.7	25	800.4	42.5	775	1.0328
2035	2	45.7	25	800.4	42.5	775	1.0328
2040	2	45.6	25	800.4	42.5	775	1.0328
2045	2	46.6	25	800.4	42.5	775	1.0328
2130	3	44.6	24.9	1000.3	63.0	967	1.0345
2135	3	44.6	24.9	1000.3	63.0	967	1.0345
2140	3	44.7	24.9	1000.3	63.0	967	1.0345
2145	3	44.7	24.9	1000.3	63.0	967	1.0345
2150	3	44.6	24.9	1000.3	63.0	967	1.0345
2155	3	44.5	24.9	1000.3	63.0	967	1.0345

REMARKS

22596

FIGURE 11

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Primary Coolant Pressure Drop
TEST ENGINEER E. K. Moore
NAME OF RIG 61 and 61 A
PROJECT & ENG ORDER NO. C43-400-001B

SHEET 2 OF 2 DATE 5-18-76
TEST PLAN NO C 43-002
MODEL NO. LLL HX-II
PART NO. SVSK 90348-1
SERIAL NO
OPERATORS Kulle
Primary H_2O Loop

Time	Test Point No.	Tin °F	Pin Psig	Flow lb/hr	ΔP "H_2O	Flow CPS	K Factor
2300	4	44.5	30.5	1201.4	86.0	1160	1.0357
2305	4	44.5	30.5	1201.4	86.0	1160	1.0357
2310	4	44.6	30.5	1201.4	86.0	1160	1.0357
2315	4	44.6	30.5	1201.4	86.0	1160	1.0357
2320	4	44.6	30.5	1201.4	86.0	1160	1.0357
2325	4	44.6	30.5	1201.4	86.0	1160	1.0357

REMARKS: Point rerun prior to switching H_2O line
SEE log sheet 22495

22599

Figure 11

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Primary Coolant Pressure Drop

TEST ENGINEER E. K. Moore

NAME OF RIG 61 and 61A

PROJECT & ENG. ORDER NO. C43-400-001B

SHEET 2 OF 2 DATE 5-19-76

TEST PLAN NO. C43-002

MODEL NO. LLC HX - II

PART NO. SVSK 90348-1

SERIAL NO.

OPERATORS Kulle

Primary H_2O Loop

Time	Test Point No.	Tin °F	Pin Psig	Flow #/HR	ΔP "H_2O	Flow CPS	K Factor
1605	4	44.5	26.0	1201.4	86.0	1160	1.0357
1610	4	44.5	26.0	1201.4	86.0	1160	1.0357
1615	4	44.4	26.0	1201.4	86.0	1160	1.0357
1620	4	44.4	26.0	1201.4	86.0	1160	1.0357
1625	4	44.4	26.0	1201.4	86.0	1160	1.0357
1630	4	44.4	26.0	1201.4	86.0	1160	1.0357

REMARKS:

22495

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST Primary Coolant Pressure Drop

TEST ENGINEER E. K. Moore

NAME OF RIG 61 and 61A

PROJECT & ENG ORDER NO C43-400-601B

SHEET 1 OF 1 DATE 5-20-76

TEST PLAN NO C43-002

MODEL NO LLLHX-II

PART NO. SVSK 90348-1

SERIAL NO.

OPERATORS Kulle

Primary H_2O Loop

Time	Test Point No.	TIN °F	PIN PSIG	Flow lb/hr	ΔP "H_2O	Flow CPS	K Factor
2110	4	44.7	60	1201.4	86.0	1160	1.0357
2115	4	44.7	60	1201.4	86.0	1160	1.0357
2120	4	44.7	60	1201.4	86.0	1160	1.0357
2125	4	44.7	60	1201.4	86.0	1160	1.0357
2130	4	44.7	60	1201.4	86.0	1160	1.0357
2135	4	44.7	60	1201.4	86.0	1160	1.0357

REMARKS.

22498

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Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: SLURPEP ΔP w/o Air Flow

TEST ENGINEER: E.K. Moore

NAME OF RIG: 61 and 61A

PROJECT & ENG. ORDER NO.: C43 - 400 - 001B

SHEET 1 OF 1 DATE 5-20-76

TEST PLAN NO. C43-002

MODEL NO. ULHX - II

PART NO. SVSK 90348-1

SERIAL NO.

OPERATORS Kulle

Time	Test Point No.	Tin °F	Pin PSIA	Flow lb/hr	ΔP "H2O		Flow %
2210	1	67.9	14.6	20	.34		22*
2220	2	68.2	14.6	30	.67		32.5
2230	3	68.3	14.6	40.	1.06		42.5
2240	4					unable To get required lb/hr.	

REMARKS: Flowrator FR 116-34
* curve extended

22499

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Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: PERFORMANCE Dry

TEST ENGINEER: E. Moore

NAME OF RIG: 61 ; 61A

PROJECT & ENG. ORDER NO.: C43-400-001B

SHEET 1 OF — DATE 5-21-76

TEST PLAN NO. C43-002

MODEL NO. LLL HX II

PART NO. SVSK 90348-1

SERIAL NO.

OPERATORS Kulle

TEST POINT No.	TIME	CIRC	← H2O LOOP FLOW CPS*	FLOW #/Hr.	TIN °F	TOUT °F	ΔT °F	PIN PSIG	ΔP → "H2O	SLURP ΔP "H2O	SLURP FLOW #/Hr	← AIR SIDE PIN "H2O	POUT "H2O	ΔP "H2O	TIN °F	TOUT °F	ΔT °F	FLOW → #/min	DEWPOINT D.P.IN °F	DP OUT °F	CON DEG RATE OUT cc/min	H2O/H2O IN-IN ΔT °F
3	1820	Prim.	976	1009.7	43.2	62.8	19.5	25.0	62.0	.61	36	.94	.40	.55	104.4	46.1	58.2	22.76	26.5	22.5	0	61.4
3	1825	Prim	975	1008.6	43.2	62.7	19.8	25.0	62.0	.60	36	.93	.40	.54	104.5	46.0	58.4	22.77	26.0	22.0	0	61.6
3	1830	Prim	975	1008.6	43.1	62.7	19.6	25.0	61.9	.60	36	.94	.40	.55	104.5	46.0	58.4	22.74	25.5	22.5	0	61.5
3	1835	Prim	975	1008.6	43.1	62.8	19.6	25.0	62.0	.60	36	.94	.39	.54	104.5	46.1	58.3	22.75	26.0	23.0	0	61.6
3	1840	Prim	977	1010.7	43.1	62.9	19.7	25.0	62.0	.60	36	.94	.40	.54	104.7	46.2	58.4	22.76	26.0	23.0	0	61.5
3	1845	Prim	975	1008.6	43.3	62.9	19.5	25.0	62.0	.60	36	.93	.40	.54	104.5	46.3	58.0	22.74	26.0	23.0	0	61.1
2		Prim	990	1024.3	49.2	60.6	11.5	25.0	62.5	.58	36	1.03	.42	.60	84.8	50.9	33.7	23.52	25.0	22.0	0	36.0
2		Prim	990	1024.3	49.1	60.6	11.6	25.0	62.5	.58	36	1.03	.42	.60	85.0	50.8	34.1	23.51	24.5	22.0	0	35.9
2		Prim	993	1027.4	49.0	60.7	11.6	25.0	62.5	.58	36	1.02	.42	.59	85.2	50.8	34.2	23.52	24.5	22.0	0	36.1
2		Prim	990	1024.3	49.1	60.8	11.7	25.0	62.5	.58	36	1.03	.42	.60	85.3	50.9	34.3	23.50	24.5	22.5	0	36.1
2		Prim	992	1026.4	49.1	60.9	11.8	25.0	62.5	.58	36	1.03	.42	.60	85.4	50.9	34.4	23.54	24.5	22.5	0	36.2
2		Prim	990	1024.3	49.1	61.0	11.8	25.0	62.5	.58	36	1.03	.42	.60	85.5	51.0	34.5	23.53	24.5	22.5	0	36.3
1		Prim	449	462.5	42.7	50.5	8.0	25.1	17.0	.83	36	.10	0	.10	79.7	43.7	35.9	7.67	7.0	1.0	0	37.1
1		Prim	448	461.4	42.1	50.6	8.2	25.1	17.0	.83	36	.10	0	.10	79.5	43.8	35.6	7.64	7.0	1.0	0	37.0
1		Prim	450	463.5	41.8	50.3	8.1	25.1	17.0	.83	36	.10	0	.10	79.2	43.6	35.5	7.68	7.0	1.0	0	36.9
1		Prim	448	461.4	41.9	50.5	8.3	25.1	17.0	.83	36	.10	0	.10	79.6	43.6	36.0	7.69	7.0	1.0	0	37.6
1		Prim	447	460.4	41.8	50.4	8.6	25.1	17.0	.83	36	.10	0	.10	79.9	43.6	36.3	7.64	7.0	1.0	0	38.1
1		Prim	445	458.3	41.9	50.6	8.5	25.1	17.0	.83	36	.10	0	.10	80.0	43.6	36.3	7.69	7.0	1.0	0	38.0

REMARKS:
* K FACTOR for 460 = 1.03
K FACTOR for 1025 = 1.0347
K FACTOR for 1009 = 1.0345

14140

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Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

UA

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: Performance Dry + Wet
TEST ENGINEER: E. Moore
NAME OF RIG: 61 : 61 A
PROJECT & ENG. ORDER NO.: C43-400-001B

SHEET 1 OF   DATE 5/24/76
TEST PLAN NO C43-002
MODEL NO. LLL Hx-II
PART NO. SVSK 90378-1
SERIAL NO
OPERATORS SANDBERG

TEST POINT	TIME	CIRC	FLOW	FLOW	TIN	TOUT	ΔT	PIN	ΔP	SLURP ΔP	SLURP FLOW	PIN	POUT	ΔP	TIN	TOUT	ΔT	FLOW	DP IN	DP OUT	CONDENSATE OUT	H_2O/AIR IN/IN ΔT
NO			CPS	#/HR	°F	°F	°F	PSIG	"H_2O	"H_2O	#/HR	"H_2O	"H_2O	"H_2O	°F	°F	°F	#/MIN	°F	°F	cc/MIN	°F
3	10:40	SEC.	976	1009.6	43.5	63.4	19.9	25.0	56.5	.62	36	.92	.38	.53	103.4	46.3	56.9	22.76	21.0	17.0	0	60.3
3	10:45	SEC	976	1009.6	43.4	63.6	20.2	25.0	56.5	.62	36	.91	.38	.54	103.9	46.4	57.3	22.75	21.0	17.0	0	60.7
3	10:50	SEC	976	1009.6	43.5	63.6	20.1	25.5	56.5	.62	36	.91	.38	.54	104.0	46.5	57.2	22.76	21.0	17.0	0	60.7
3	10:55	SEC	976	1009.6	43.6	63.7	20.1	25.5	56.5	.62	36	.91	.38	.55	104.2	46.5	57.3	22.76	21.0	17.5	0	61.0
3	11:00	SEC	976	1009.6	43.6	63.8	20.2	25.5	56.5	.62	36	.91	.38	.55	104.1	46.6	57.2	22.76	21.0	17.5	0	61.1
3	11:05	SEC	976	1009.6	43.6	63.9	20.3	25.5	56.5	.62	36	.91	.38	.55	104.3	46.6	57.5	22.76	21.0	18.0	0	61.5
								WET														
																					BURETT START	
3	12:50	SEC	977	1010.7	43.3	66.5	23.2	25.0	55.5	AVG 2.45	36	1.04	.40	.65	103.5	49.3	54.0	22.76	58.0	47.0	1000	60.7
	12:55	SEC	977	1010.7	43.5	66.5	23.0	25.0	55.0	2.45	36	1.04	.40	.65	103.7	49.4	54.2	22.76	58.0	47.0	840	60.8
	13:00	SEC	976	~~1009~~ 1009.6	43.5	66.5	23.0	25.0	55.5	2.35/2.50	36	1.04	.40	.65	103.7	49.4	53.9	22.76	58.0	47.0	745	60.5
	13:05	SEC	976	1009.6	43.6	66.0	22.5	25.0	55.5	AVG 2.45	36	1.04	.40	.65	103.6	49.4	54.1	22.76	57.5	47.0	600	60.6
	13:10	SEC	977	1010.7	43.4	66.2	22.8	25.0	55.5	AVG 2.45	36	1.04	.40	.66	103.6	49.4	54.1	22.76	57.8	47.0	480	60.6
3	13:15	SEC	977	1010.7	43.4	66.2	22.8	25.0	55.5	AVG 2.45	36	1.04	.40	.66	103.7	49.3	54.1	22.76	57.8	47.0	350	60.7
																				TOTAL	650cc	25/MIN.

CONDENSATE FLOW = 26 cc/MIN

REMARKS:
K-FACT. @ 460 1.03 =
@ 1025 1.0347 =
@ 1009 1.0345 =

14141

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: PERFORMANCE WET
TEST ENGINEER: E. MOORE
NAME OF RIG: 61 + 61A
PROJECT & ENG. ORDER NO.: C43-400-001 B

SHEET ___ OF ___ DATE 5/24/74
TEST PLAN NO: C43-002
MODEL NO.: LLL HX-II
PART NO: SVSK 90348-1
SERIAL NO.:
OPERATORS: SANDBERG
C.B 29.55"HG ABS

TEST POINT	TIME	← CIRC	COOLANT FLOW	H2O FLOW	TIN	TOUT	ΔT	PIN	ΔP →	SLURPER ΔP	SLURPER FLOW	← AIR CIRCUIT PIN	POUT	ΔP	TIN	TOUT	ΔT	FLOW	DP IN	DP OUT →	COND. OUT	H2O IN/AIR IN ΔT
			CPS	#/HR	°F	°F	°F	PSIG	"H2O	"H2O	#/HR	"H2O	"H2O	"H2O	°F	°F	°F	#/MIN	°F	°F		°F
3	13:40	PRIM	976	1009.6	43.8	65.7	22.1	25.0	66.6	2.42	36	1.04	.40	.66	103.8	49.2	54.3	22.76	57.5	48.0	START 1000	60.3
3	13:45	PRIM	976	1009.6	43.6	65.7	22.1	25.0	66.0	AVG 2.42	36	1.04	.40	.66	103.9	49.2	54.4	22.76	57.5	48.0	867	60.3
3	13:50	PRIM	976	1009.6	43.6	65.6	22.1	25.0	66.0	AVG 2.42	36	1.04	.40	.65	103.8	49.2	54.4	22.77	57.5	48.0	740	60.3
3	13:55	PRIM	976	1009.6	43.5	65.6	22.1	25.0	66.0	AVG 2.42	36	1.04	.40	.65	103.8	49.2	54.6	22.76	57.7	48.0	618	60.3
3	14:00	PRIM	976	1009.6	43.6	65.5	22.0	25.0	66.0	AVG 2.42	36	1.04	.40	.65	103.6	49.2	54.4	22.76	57.7	48.0	490	60.1
3	14:05	PRIM	976	1009.6	43.6	65.6	22.1	24.75	66.0	AVG 2.42	36	1.04	.40	.65	103.9	49.1	54.6	22.76	57.7	48.0	END 360	60.3
																			TOTAL		640cc/25 MIN	
																					25.6 cc/MIN	
																					START	
2	14:50	PRIM	991	1025.3	49.1	62.0	13.0	25.5	67.5	AV 2.3	36	1.11	.43	.68	85.6	52.1	33.5	23.51	55.5	51.0	1000	36.6
2	14:55	PRIM	991	1025.3	49.0	61.9	12.9	25.5	67.5	2.3	36	1.11	.43	.68	85.5	52.0	33.2	23.51	55.5	50.5	940	36.5
2	15:00	PRIM	991	1025.3	49.1	61.8	12.8	25.5	67.5	2.3	36	1.11	.43	.68	85.1	52.0	33.0	23.51	55.5	50.5	886	36.2
2	15:05	PRIM	992	1026.4	49.1	61.8	12.9	25.5	68.0	2.3	36	1.11	.43	.67	85.3	52.0	33.1	23.53	55.5	50.5	835	36.4
2	15:10	PRIM	991	1025.3	48.9	61.8	12.8	25.5	67.5	AV 2.3	36	1.10	.43	.68	85.3	52.1	33.1	23.52	55.5	50.5	780	36.3
2	15:15	PRIM	991	1025.3	48.9	61.8	12.8	25.5	67.5	2.3	36	1.10	.43	.68	85.2	52.1	33.0	23.52	55.5	50.5	STOP 725	36.2
																			TOTAL		275 cc/25 MIN	
																					11 cc/MIN	

REMARKS
K FACTOR @ 460 = 1.03
@ 1025 = 1.0347
@ 1009 = 1.0345

14142

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: PERFORMANCE
TEST ENGINEER: E. MOORE
NAME OF RIG: G1 + G1A
PROJECT & ENG. ORDER NO.: C43-400-001 B

SHEET OF DATE 5-24-76
TEST PLAN NO. C43-002
MODEL NO. LLL HX II
PART NO. SVSK 90348-1
SERIAL NO
OPERATORS Creighton

TEST		COOLANT H2O								SLURPER		AIR CIRCUIT									COND	H2O IN / AIR IN
POINT	TIME	CIRC	FLOW	FLOW	TIN	TOUT	ΔT	PIN	ΔP	ΔP	FLOW	PIN	POUT	ΔP	TIN	TOUT	ΔT	FLOW	DP IN	DP OUT	OUT	ΔT
			CPS	#/HR	°F	°F	°F	PSIG	"H2O	H2O	#/HR	"H2O	"H2O	"H2O	°F	°F	°F	#/MIN	°F	°F	Start	°F
1		Prim	446	459.4	42.1	53.3	11.3	25.5	21.5	2.48	36	.13	0.	.13	79.8	44.8	35.0	7.68	53.5	42.8	1000	38.0
1		Prim	446	459.4	42.1	53.2	11.2	25.5	21.5	2.48	36	.13	0.	.13	79.8	44.8	35.0	7.67	53.6	42.8	967	37.8
1		Prim	447	460.4	42.1	53.2	11.3	25.5	21.5	2.48	36	.13	0.	.13	80.0	44.8	35.0	7.68	53.6	42.8	930	38.0
1		Prim	447	460.4	42.1	53.1	11.2	25.5	21.5	2.48	36	.13	0.	.13	80.0	44.8	35.1	7.69	53.5	42.8	894	38.0
1		Prim	446	459.4	42.1	53.2	11.2	25.5	21.5	2.48	36	.13	0.	.13	80.1	44.8	35.1	7.69	53.5	42.8	860	38.0
1		Prim	446	459.4	42.1	53.1	11.2	25.5	21.5	2.48	36	.13	0.	.13	80.0	44.9	35.0	7.69	53.6	42.8	824	38.0
																				Total	176cc/25min	
																					7.04cc/min	

REMARKS:
K Factor @ 460# = 1.03
@ 1025# = 1.0347

C.B @ 70° 29.53 "Hg
Psia 14.5005

14143

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST P453.F

TYPE OF TEST: Perf
TEST ENGINEER: E Moore
NAME OF RIG: 61 961A
PROJECT & ENG. ORDER NO.: C43-400-001B

SHEET OF DATE 5-24-76
TEST PLAN NO. C43-002
MODEL NO. LLL HX II
PART NO. SVSK 90348-1
SERIAL NO.
OPERATORS Creighton / SANDBERG

Test Point	Time	Circ	Flow	Coolant H_2O Flow	Tin	Tout	ΔT	Pin	ΔP	Slurpe ΔP	Slurpe Flow	Tin	Pin	Pout	Air Circuit ΔP	Tin	Tout	ΔT	Flow	DPin	DPout	H_2O/Air Inlet ΔT
			CPS	#/hr	°F	°F	°F	PSIG	"H_2O	"H_2O	#/hr	°F	"H_2O	"H_2O	"H_2O	°F	°F	°F	#/min	°F	°F	°F
2		Prim	991	1025.4	48.3	60.9	12.2	25.3	68	.43	30	60	1.02	.43	.6	85.7	50.2	35.3	23.54	26.5	24.8	37.1
2		Prim	991	1025.4	48.2	60.4	11.8	25.5	68.2	.43	30	60	1.02	.43	.6	85.4	50.2	35.2	23.51	26.6	24.8	37.0
2		Prim	991	1025.4	48.3	60.5	11.8	25.4	68.5	.43	30	60	1.02	.43	.6	85.7	50.3	35.2	23.51	26.7	24.8	37.1
2		Prim	991	1025.4	48.4	60.5	11.7	25.4	68.5	.43	30	60	1.02	.43	.6	85.7	50.4	35.2	23.51	26.8	24.9	36.9
2		Prim	991	1025.4	48.4	60.6	11.8	25.4	68.5	.43	30	60	1.02	.43	.6	85.6	50.4	35.2	23.51	27.0	25.2	36.9
2		Prim	991	1025.4	48.4	60.6	11.7	25.4	68.2	.43	30	60	1.02	.43	.6	85.7	50.5	35.2	23.51	27.2	25.3	36.9
	SLURP COND-								5/25/76													
2	1	PRIM	992		49.9	61.1	11.3	25.5	68.5	.04	20.	61.0	1.04	.46	.6	84.7	51.5	33.0	23.52	25.0	23.0	34.9
	2	PRIM	992		49.9	61.2	11.4	25.5	68.5	.36	30.	61.0	1.01	.43	.6	84.9	51.6	33.1	23.51	25.5	23.5	35.0
	3	PRIM	992		49.9	61.3	11.4	25.5	68.5	.73	40.	61.0	.98	.40	.6	85.1	51.6	33.2	23.51	26.0	24.0	35.2
	*4	PRIM	991		49.6	61.3	11.5	25.5	68.5	1.5	50	58.0	.90	.33	.58	85.3	51.5	33.6	23.51	27.0	25.0	35.4
	*1	PRIM	991		49.8	61.4	11.5	25.5	68.5	.08	20	58.0	1.05	.46	.6	85.5	51.6	33.8	23.51	26.0	24.0	35.6
	*2		991		49.7	61.4	11.5	25.5	68.5	.45	30	58.0	1.0	.43	.58	85.6	51.6	33.8	23.51	26.0	24.0	35.7
	*3		991		49.7	61.4	11.6	25.5	68.5	.93	40	57.0	.96	.39	.58	85.6	51.5	33.9	23.51	26.5	24.5	35.9
2	*4	PRIM	991		49.6	61.3	11.7	25.5	68.5	1.5	50	56.0	.92	.34	.58	85.7	51.4	34.1	23.51	27.2	25.5	36.1

REMARKS:
* BYPASSED COLLECTION BOTTLES TO SECURE HIGHER FLOW ON F/R.

14145

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: COOLANT RIG TARE
TEST ENGINEER: E. MOORE
NAME OF RIG: GI + GI A
PROJECT & ENG. ORDER NO.: C43-400-001B

SHEET OF DATE 5/25/76
TEST PLAN NO. ENG INSTR TABLE III
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS SANDBERG

LOOP	TEST POINT	TIN		PIN		FLOW	FLOW	K FACTOR		ΔP
		°F		PSIG		CPS	#/HR			" H_2O
SEC.	4	44.5		25.5		1160	1201.4	1.0357		23.0
SEC	3	45.4		25.5		965	1001.3	1.0345		16.2
SEC.	2	45.2		25.0		775	800.4	1.0328		11.2
SEC.	1	44.7		25.0		582	600.3	1.0315		6.5
PRIM	4	45.6		25.0		1160	1201.4	1.0357		37.0
PRIM	3	45.3		24.5		968	1001.3	1.0345		26.5
PRIM	2	44.9		25.0		775	800.4	1.0328		17.5
PRIM	1	45.0		24.5		582	600.3	1.0315		10.5

REMARKS:
INLET & OUTLET CONNECTED BY 5/8 O.D TUBE. 3½" LG. (17/32 I.D)

14146

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: WEIGHT
TEST ENGINEER: E. K. MOORE
NAME OF RIG: 12
PROJECT & ENG ORDER NO.: C43-100-001B

SHEET 1 OF
DATE 5-27-76
TEST PLAN NO. C43-002
MODEL NO. LLL HX II
PART NO SVSK 90348-1
SERIAL NO.
OPERATORS SLAHTOSKY

	FIRST DRY CYCLE	SECOND DRY CYCLE
START TIME	0930	12:30
END TIME	1130	14:30
TEMP @ START	105.0°	130.0
TEMP @ END	145.0°	135.0
VACUUM @ START	.6 MM	.5
VACUUM @ END	.3 MM	.3
TIME @ WEIGHING	11:30	14:45
WEIGHT	19.26	19.26

REMARKS:

14116

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: PROOF + LKG
TEST ENGINEER: E.K. MOORE
NAME OF RIG: 64
PROJECT & ENG. ORDER NO.: C43-400-001 B

SHEET 1 OF
DATE 5-28-76
TEST PLAN NO C43-503 A
MODEL NO. LLL HX II
PART NO. SVSK 96348-1
SERIAL NO.
OPERATORS SLAHTOSKY

	PRIMARY LOOP	SECONDARY LOOP	AIR LOOP
BAROMETRIC PRESS, "HG	30.03	30.03	30.03
AMB. TEMP. °F	70.0	70.0	70.0
INITIAL PRESS PSIG	90.0	90.0	1.8
ITEM TEMP. °F	72.0	72.0	72.0
PRESS IN 10. MIN. PSIG	90.0	90.0	1.79
" 15. " "	90.0	90.0	1.77
" 20. " "	90.0	90.0	1.74
" 25. " "	90.0	90.0	1.72
" 30. " "	90.0	90.0	1.70
TEMP 10. MIN °F	72.0	72.0	72.0
" 15 " "	72.0	72.0	72.0
" 20 " "	72.0	72.0	72.0
" 25 " "	72.0	72.0	72.0
" 30 " "	72.0	72.0	72.0

PRESS @ 89.5 IN 90.0 MINUTES PRIMARY LOOP

REMARKS

22548

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: LKG.

TEST ENGINEER: E. K. MOORE

NAME OF RIG: 64

PROJECT & ENG ORDER NO.: C43-400-001B

SHEET 1 OF

DATE 6-7-76

TEST PLAN NO. 10 C

MODEL NO. LLL HX

PART NO. SVSK 90348

SERIAL NO.

OPERATORS SLAHTOSKY

PIN PSIG	TIME MINUTES
1.8	0
1.5	60.

REMARKS.

14120

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: PROOF + LKG.
TEST ENGINEER: E.K. MOORE
NAME OF RIG: 64
PROJECT & ENG. ORDER NO: 543-400-001B

SHEET 1 OF   DATE 6-10-76
TEST PLAN NO. 1.0C 4C43-002 TP4.
MODEL NO. LLL HX II
PART NO SVSK90348-1
SERIAL NO.
OPERATORS SLAHTCSKY

		PRIMARY LOOP
BAROMETRIC PRESS. IN HG		29.72
AMB. TEMP. °F		72.0
INITIAL PRESS PSIG		90.0
INLET TEMP °F		73.0
PRESS IN	10 MIN PSIG	90.0
	15 "	90.0
	20	89.9
	25	89.9
	30	89.85
	50	89.8
	60	89.8
13:50	70	89.75
10:20	110	89.6
12:10	120	89.55
	212	89.00
	6-11-76	

INVERTED BEAKER LKG. PRIMARY LOOP TO SECONDARY LOOP = 8.0 cc/HR.

REMARKS:

14131

HSF 175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

UA

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: PERFORMANCE
TEST ENGINEER: E. K. MOORE
NAME OF RIG: ~~57~~ 61, 61A
PROJECT & ENG. ORDER NO.: C43-400-001B

SHEET: 1A OF
DATE: 6/21/76
TEST PLAN NO: LLC. C43-002 P4.5 TABLE V
MODEL NO.: LLL HX II
PART NO.: SVSK 90348-1
SERIAL NO.:
OPERATORS: Sandberg Creighton

TEST POINT RUN No	TIME	H_2O CIRC.	H_2O FLOW CPS	H_2O FLOW #/HR	K FACTOR	H_2O IN °F	H_2O OUT °F	H_2O ΔT °F	H_2O PIN PSIG.	H_2O ΔP "H_2O	AIR FLOW #/MIN.	AIR FLOW #/HR.	TIN AIR °F	TOUT AIR °F	ΔT AIR °F	PIN AIR "H_2O	POUT AIR "H_2O	ΔP AIR "H_2O	AIR IN / H_2O IN ΔT °F	DP IN °F	DP OUT °F
1	1430	PRIM	443	459.8	1.038	42.0	53.8	12.4	26.0	21.2	7.62	457.2	79.9	45.0	34.6	+.13	-.08	.22	38.1	55.5	43.0
1	1435		443	459.8		42.1	53.8	12.3	26.0	21.2	7.62	457.2	79.8	45.1	34.7	+.13	-.08	.22	38.0	55.5	43.0
1	1440		443	459.8		41.9	53.8	12.3	26.0	21.2	7.62	457.2	79.9	45.1	34.7	+.13	-.08	.22	38.2	55.5	43.0
1	1443		442	458.7		42.1	53.8	12.3	26.0	21.2	7.63	457.2	79.8	45.0	34.7	+.13	-.08	.22	38.2	55.5	43.0
1	1450		442	458.7		42.2	53.8	12.3	26.0	21.2	7.63	457.2	79.8	45.1	34.7	+.13	-.08	.22	38.1	55.5	43.0
1	1455		443	459.8	1.038	42.2	53.8	12.3	26.0	21.2	7.63	457.2	79.8	45.1	34.7	*.18	*-.08	.22	38.1	55.5	43.0
1A	1510		443	459.8	1.038	42.3	53.9	12.5	26.0	21.2	7.69	461.4	79.8	45.1	34.7	-.15	-.22 / [illegible]	.22	38.2	53/57 ~~53.0~~	43.0
1A	1520		443	459.8	1.038	42.4	53.9	12.1	26.0	21.2	7.69	461.4	79.7	45.1	34.5	-.15	-.42	.22	38.1	55.5	43.0
1A	1530		443	459.8	1.038	42.5	53.8	12.4	26.0	21.2	7.69	461.4	79.8	45.1	34.5	-.14	-.40	.22	38.1	55.5	43.0
1A	1540		443	459.8	1.038	42.4	53.8	12.5	26.0	21.2	7.69	461.4	79.8	45.2	34.5	-.15	-.41	.23	38.1	55.5	43.0
1B			443	459.8	1.038	41.9	53.4	12.2	26.0	21.2	7.69	461.4	79.5	44.9	34.4	-.4	-.66	.24	38.1	55.8	43.0
1B			443	459.8	1.038	42.1	53.4	12.2	26.0	21.2	7.69	461.4	79.3	44.9	34.3	-.4	-.66	.24	37.8	56.0	43.0
1B			443	459.8	1.038	41.9	53.3	12.1	26.0	21.2	7.69	461.4	79.4	44.9	34.4	-.4	-.66	.24	38.1	56.0	43.0

REMARKS.
* UNSTABLE

13662

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: PERFORMANCE
TEST ENGINEER: E.K MOORE.
NAME OF RIG: ~~[illegible]~~ 61, 61A
PROJECT & ENG. ORDER NO.: C43-400-001 B

SHEET: 1B OF
DATE: 6-21-76
TEST PLAN NO.: C43-002 P4.5 TABLE V
MODEL NO.: LLL HX III
PART NO.: SVSK 90348-1
SERIAL NO.:
OPERATORS: SANdberg Creighton

TEST POINT RUN #	SLURP IN "H2O	SLURP OUT "H2O	SLURP ΔP "H2O	STEAM H2O * FLOW SCALE	STEAM H2O * FLOW #/HR	COND. BURETT CC	COND. cc/5 MIN	cc/30 MIN	#/HR	SLURPER SEPARATOR ORIFICE " P IN H2O	SLURPER SEPARATOR ORIFICE " ΔP H2O	CB. " HG AB.
1	-.08	-2.6	2.48	8	1.4	500/462	38			-4.6	.38	29.92
1	-.08	-2.6	2.48	8	1.4	462/426	36			-4.6	.38	29.92
1	-.08	-2.55	2.47	8	1.4	426/387	39			-4.6	.38	29.92
1	-.08	-2.55	2.48	8	1.4	388/350	37.			-4.6	.38	29.92
1	-.08	-2.55	2.48	8	1.4	350/311	39			-4.6	.38	29.92
1	-.06	-2.6	2.48	8	1.4	311/272	39	228	1.00	-4.6	.38	29.92
							cc/10 MIN					
1A	-.42	-2.1	1.73	8	1.4	500/400	100.			-3.6	.25	29.92
1A	-.42	-2.1	1.74	8	1.4	400/315	85.			-3.6	.25	29.92
1A	-.40	-2.1	1.73	8	1.4	500/401	99		1.[illegible]	-3.6	.25	29.92
1A	-.41	-2.1	1.75	8	1.4	500/413	87.	371	1.23	-3.6	.25	29.92
							cc/10 MIN					
1B	-.66	-1.7	1.06	8	1.4	500/398	102			-2.6	.125	29.89
1B	-.66	-1.7	1.06	8	1.4	500/400	100			-2.6	.125	29.89
1B	-.66	-1.7	1.08	8	1.4	500/398	102.	304	1.34	-2.6	.13	29.89

REMARKS:
* F/R 102-22 (1/8-20 SA)

13663

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST	Perf.	SHEET	1A OF
TEST ENGINEER	EK Moore	DATE	6-21-76
NAME OF RIG	61, 61A	TEST PLAN NO	C43-002 P 45 Table V
PROJECT & ENG. ORDER NO	C43- 400- 001B	MODEL NO.	LLL HX II
		PART NO.	SV SK 90348-1
		SERIAL NO.	
		OPERATORS	Creighton

Test Point No	Time	H_2O Circ	H_2O Flow CPS	H_2O Flow #/Hr	K Factor	H_2O In °F	H_2O out °F	H_2O ΔT °F	H_2O Pin PSIG	H_2O Pout "H_2O		Air Flow #/min	Air Flow #/Hr	Tin Air °F	Tout Air °F	ΔT Air °F	Pin Air "H_2O	Pout Air "H_2O	ΔP Air "H_2O	Air in/H_2O in ΔT °F	DP In °F	DP out °F
* 2		Prim	986	1024.94	1.0395	48.9	62.7	14.1	25.2	65		23.54	1412.4	85.3	52.7	32.4	1.80	.58	1.18	36.4	56/60	51.8
2			988	1027.03	1.0395	49.0	62.6	14.0	25.2	67		23.54	1412.4	85.3	52.7	32.3	1.80	.58	1.18	36.4	56/60	51.9
2			986	1024.94	1.0395	49.1	62.7	13.7	25.2	67		23.54	1412.4	85.1	52.6	32.4	1.80	.58	1.18	36.2	56/60	51.8
* 2A		Prim	984	1022.81	1.0395	49.0	62.8	13.9	25.2	66.5		23.54	1412.4	85.4	52.9	32.3	1.38	.22	1.17	36.2	56/60	51.8
2A			985	1023.91	1.0395	49.1	62.8	13.9	25.2	67.0		23.54	1412.4	85.4	53.0	32.3	1.38	.22	1.17	36.2	56/60	51.8
2A			987	1025.99	1.0395	49.1	62.8	13.8	25.2	67.0		23.54	1412.4	85.4	52.9	32.4	1.38	.22	1.17	36.2	56/60	51.8
* 2B		Prim	988	1027.03	1.0395	49.1	62.8	13.9	25.0	67.5		23.54	1412.4	85.6	53.0	32.4	1.0	-.18	1.17	36.4	56/60	51.8
2B			986	1024.94	1.0395	49.6	62.7	13.9	26.0	67.5		23.54	1412.4	85.6	52.8	32.6	1.02	-.18	1.17	36.7	56/60	51.8
2B.			988	1027.03	1.0395	49.1	62.7	13.7	25.0	68.0		23.54	1412.4	85.7	52.8	32.6	1.02	-.18	1.17	36.4	56/66	51.7

REMARKS:
* Air Pin Unstable, Inlet Dew Point also

13664

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: Perf.
TEST ENGINEER: E K Moore
NAME OF RIG: 61, 61A
PROJECT & ENG. ORDER NO.: CH3-400-001B

SHEET 1B OF
DATE 6-21-76
TEST PLAN NO. CH3-002 IV 4.5 Table V
MODEL NO. LLL HX-II
PART NO. SVSK 90348-1
SERIAL NO.
OPERATORS Creighton

Test Point No		SLURP In "H2O	SLURP out "H2O	SLURP ΔP "H2O		Steam H2O *Flow % Scale	#/Hr		Cond. Burett cc	Cond cc 10/min	Cond cc 30/min	Cond #/Hr	SLURP Separator Pin "H2O	PER "H2O		CB "Hg/AB
2		.58	-1.9	2.49		10.3	2.3		500/318	182			-4.5	.43		29.89
2		.58	-1.9	2.5		10.3	2.3		500/320	180		/	-4.5	.43		29.89
2		.58	-1.9	2.5		10.3	2.3		500/318	182	544	2.3986	-4.5	.43		29.89
~~2A~~		~~.22~~	~~-1.8~~	~~1.94~~									-3.4			
2A		.22	-1.8	2.06		10.3	2.3		500/320	180			-3.5	.285		29.89
2A		.22	-1.8	2.09		10.3	2.3		500/325	175		/	-3.5	.285		29.89
2A		.22	-1.85	2.07		10.3	2.3		500/320	180	535	2.3589	-3.5	.280		29.89
2B		-.18	1.8	1.63		10.3	2.3		500/324	176			-2.7	.140		28.89
2B		-.18	1.75	1.62		10.3	2.3		500/326	174		/	-2.7	.140		28.89
2B		-.18	1.8	1.63		10.3	2.3		500/326	174	524	2.310	-2.7	.140		28.89
3																29.97

REMARKS:
* F/R 102-22 (1/8 - 20 SA)

13665

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: PERFORMANCE
TEST ENGINEER: E.K. MOORE
NAME OF RIG: G1 + G1A
PROJECT & ENG. ORDER NO: C43-400-001B

SHEET 1 OF DATE 6-22-76
TEST PLAN NO C43-002 PH-S TABLE V
MODEL NO. LLL HX II
PART NO. SVSK 90348-1
SERIAL NO.
OPERATORS SANDBERG

TEST POINT NO	TIME	H2O CIRC	H2O FLOW CPS	H2O FLOW #/HR	K FACTOR	H2O T IN °F	H2O T OUT °F	H2O T ΔT °F	H2O PIN PSIG	H2O ΔP "H2O		AIR FLOW #/MIN	AIR FLOW #/HR	TIN AIR °F	TOUT AIR °F	ΔT AIR °F	PIN AIR "H2O	POUT AIR "H2O	ΔP AIR "H2O	AIR IN / H2O IN ΔT °F	DP IN °F	DP OUT °F
3	1000	PRIM	969	1007.2	1.0395	42.4	65.1	23.2	24.5	65.5		22.77	1366.2	104.0	48.0	55.8	*1.61	*+.56	1.12	62.4	58.0	47.0
3	1010	PRIM	968	1006.2	1.0395	42.2	65.1	23.2	24.5	66.0		22.76	1365.6	104.2	48.0	55.9	1.65	+.56	1.11	62.3	58.0	46.8
3	1020	PRIM	966	1004.1	1.0395	42.2	65.0	23.2	24.5	65.5		22.78	1366.8	104.3	47.9	56.0	1.65	+.56	1.11	62.4	58.0	46.8
3A	1050	PRIM	969	1007.2	1.0395	42.3	65.0	23.2	24.5	66.0		22.81	1368.6	104.3	47.9	56.2	1.31	+.20	1.11	62.4	58	46.8
3A	1100	PRIM	970	1008.3	1.0395	42.3	65.0	23.3	24.5	66.0		22.81	1368	104.5	47.9	56.1	1.35	+.24	1.11	62.6	58.5	47.0
3A	1110	PRIM	969	1007.2	1.0395	42.4	65.0	23.3	24.5	66.0		22.82		104.5	47.9	56.3	1.35	+.24	1.11	62.5	58.5	47.0
3B	1220	PRIM	968	1006.2	1.0395	42.0	65.1	23.4	24.5	66.0		22.81	1368.6	104.3	47.8	56.6	1.08	+.02	1.13	62.7	55/59	46.8
3B	1230	PRIM	970	1008.3	1.0395	41.9	64.8	23.3	24.5	66.0		22.80	1368	104.1	47.7	56.1	1.08	+.03	1.12	62.2	55/59	46.8
3B	1240	PRIM	970	1008.3	1.0395	42.1	64.8	23.0	24.5	66.0		22.86	1371	104.0	47.8	56.2	1.08	+.05	1.13	62.1	57/59	46.8

REMARKS:
* UNSTABLE

13666

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: PERFORMANCE
TEST ENGINEER: E. K. MOORE
NAME OF RIG: 61 + 61A
PROJECT & ENG ORDER NO.: C43-400-001B

SHEET 1A OF DATE 6-22-75
TEST PLAN NO C43-002 ¶4.5 TABLE V
MODEL NO. LLL HX II
PART NO. SVSK90348-1
SERIAL NO.
OPERATORS SANDBERG

TEST POINT		SLURP IN	SLURP OUT	SLURP ΔP		STEAM H2O FLOW			COND BURRET	COND CC	COND CC	COND #/HR.		SLURPER SEPARATOR ORIFICE			CB
		"H2O	"H2O	"H2O		% SCALE	#/HR			CC 5 MIN	CC/MIN			PIN H2O	ΔP H2O		" HG ABS
3		+.56	-2.15	2.59		15.0	4.2		500/350	150	30	3.968		-4.5	.42		30.00
3		+.56	-2.15	2.59		15.2	4.3		500/350	150	30	3.968		-4.5	.42		30.00
3		+.56	-2.15	2.59		15.0	4.2		500/350	150	30	3.968		-4.5	.42		30.0
3A		+.21	-2.0	2.13		15.2	4.3		500/352	148	29.6	3.915		-3.5	.27		30.00
3A		+.24	-2.0	2.14		15.0	4.2		500/350	150	30.0	3.968		-3.5	.27		30.00
3A		+.24	-2.0	2.14		15.0	4.2		500/352	148	29.6	3.915		-3.5	.27		30.00
										CONTINUED COLLECTION TO 250 CC/ IN 8 MIN 38 SEC. = 28.95 CC/MIN = 3.83 #/HR							
3B		-~~+~~.02	-1.8	1.74		15.0	4.2		500/352	148	29.6	3.915		-2.7	.13		29.99
3B		-~~+~~.03	-1.8	1.71		15.0	4.2		500/348	152	30.4	4.02		-2.6	.13		29.99
3B		-~~+~~.05	-1.8	1.74		15.0	4.2		500/352	148	29.6	3.915		-2.7	.13		29.99
										CONTINUED COLLECTION TO 250 CC IN 8 MIN 36 SEC = 29.06 CC/MIN = 3.84 #/HR							

REMARKS:
F/R 102-22 (1/8-20 SA)

13667

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: PERFORMANCE
TEST ENGINEER: E.K MOORE
NAME OF RIG: C1 + C1 A
PROJECT & ENG ORDER NO.: C43-400-001B

SHEET 1 OF
DATE 6-22-76
TEST PLAN NO C43-002 R4.5 TABLE V
MODEL NO. ALL HX II
PART NO SVSK90348-1
SERIAL NO.
OPERATORS SANDBERG

TEST POINT	TIME	H_2O CIR.	H_2O FLOW CPS	H_2O FLOW #/HR	K FACTOR	H_2O TIN °F	H_2O TOUT °F	H_2O ΔT °F	H_2O PIN PSIG	H_2O ΔP "H_2O		AIR FLOW #/MIN	AIR FLOW #/HR	TIN AIR °F	TOUT AIR °F	ΔT AIR °F	PIN AIR "H_2O	POUT AIR "H_2O	ΔP AIR "H_2O	AIR IN / H_2O IN ΔT°F	DP IN °F	DP OUT °F
4	1410	SEC	969	1007.2	1.0395	41.9	65.5	23.6	24.5	61.5		22.73	1363.8	104.1	48.2	55.6	1.62	.53	1.11	62.7	57/59	46
4	1420	SEC	970	1008.3		41.9	65.5	23.6	24.6	61.5		22.73	1363.8	104.1	48.3	55.6	1.62	.53	1.11	62.6	57/59	46
4	1430	SEC	970	1008.3		42.1	65.6	23.5	24.5	61.5		22.76	1365.6	104.1	48.4	55.6	1.63	.53	1.11	62.7	57/60	46
4A	1500	SEC	972	1010.3	1.0395	42.1	65.6	23.5	24.5	61.5		22.76	1365.6	104.3	48.4	55.7	1.32	.22	1.12	62.7	58/60	46.5
4A	1510	SEC	970	1008.3		42.1	65.6	23.5	24.5	61.5		22.76	1365.6	104.3	48.5	55.7	1.32	.24	1.12	62.6	57/60	46.5
4A	1520	SEC	970	1008.3		42.0	65.6	23.6	24.5	61.5		22.76	1365.6	104.2	48.5	55.7	1.32	.22	1.12	62.6	57/60	46.5
4B	1640	Sec	972	1010.3	1.0395	43.5	66.9	23.4	24.5	61.0		22.77	1366.2	104.5	49.6	54.8	1.15	-.07	1.21	61.8	57/62	47.8
4B	1650	Sec	970	1008.3		43.3	66.6	23.3	24.5	61.0		22.77	1366.2	104.6	49.5	55.0	1.15	-.07	1.21	61.9	57/62	47.5
4B	1700	Sec	970	1008.3		43.4	66.5	23.1	24.5	60.5		22.77	1366.2	104.6	49.5	55.0	1.15	-.07	1.21	61.8	57/62	47.8
4C	1750	Sec	971	1009.35	1.0395	43.5	66.7	23.2	24.5	61.0		22.77	1366.2	104.6	49.7	55.0	1.67	.50	1.17	61.8	57/62	47.8
4C	1800	Sec	970	1008.3		43.6	66.5	22.9	24.5	61.0		22.77	1366.2	104.8	49.7	54.8	1.68	.53	1.17	61.8	57/62	47.8
4C	1810	Sec	970	1008.3		43.5	66.7	23.2	24.5	61.0		22.77	1366.2	104.7	49.7	54.8	1.68	.53	1.17	61.8	57/62	47.8

REMARKS:

13669

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: PERFORMANCE
TEST ENGINEER: E.K MOORE
NAME OF RIG: C1+C1A
PROJECT & ENG ORDER NO.: C43-400-000R

SHEET 1A OF   DATE 6-22-76
TEST PLAN NO. C43-002 TP4.5 TABLE V
MODEL NO. LLL Hx II
PART NO. SVSK 90348-1
SERIAL NO.
OPERATORS SANDBERG

TEST POINT		SLURP P IN	SLURP P OUT	SLURP ΔP		STEAM H2O FLOW			COND BURRETT	COND	COND	COND		SLURP SEPARATOR ORIFICE			CB
		"H2O	"H2O	"H2O		F/R SCALE	#/HR.			cc/S MIN	cc/MIN	#/HR		P IN H2O	ΔP H2O		
4		+.53	-2.1	2.59		16.3	4.75		500/341	159	31.8	4.2		-4.4	.41		29.98
4		.53	-2.1	2.60		16.3	4.75		500/340	160	32.0	4.23		-4.4	.41		29.98
4		.53	-2.1	2.60		16.3	4.75		500/340	160	320	4.23		-4.4	.41		29.98
									→ CONTINUED COLLECTION TO 250 CC IN 7 MIN. 45 SEC = 32.25 cc/MIN = 4.26 #/HR.								
4A		.22	-2.0	2.17		16.3	4.75		500/340	160	32	4.23		-3.5	.27		29.98
4A		.23	-2.0	2.19		16.0	4.60		500/340	160	32	4.23		-3.5	.27		29.98
4A		.23	-2.0	2.19		16.2	4.70		500/341	159	31.8	4.2		-3.5	.27		29.98
									→ CONTINUED COLLECTION TO 250 CC IN 8 MIN 0 SEC = 31.25 cc/MIN = 4.13 #/HR								
4B		-.07	-1.85	1.78		16.1	4.65		500/336	165	33	4.365		-2.7	.14		29.98
4B		+.03	-1.85	1.74		16.1	4.65		500/336	164	32.8	4.339		-2.7	.14		29.98
4B		-.07	-1.85	1.73		16.2	4.70		500/335	165	33	4.365		-2.7	.14		29.98
									→ Continued Collection to 250 cc = 7.857 min = 31.82 cc/min = 4.21 #/Hr								
4C		.50	-2.0	2.51		16.2	4.70		500/335	165	33	4.365		-4.5	.41		29.98
4C		.53	-2.0	2.54		16.2	4.70		500/338	162	32.4	4.286		-4.5	.41		29.98
4C		.53	-2.0	2.56		16.2	4.70		500/335	165	33	4.365		-4.5	.41		29.98
									→ Continued collection to 250 cc = 7.8 min = 32.05 cc/min = 4.2395 #/Hr								

REMARKS:

F/R 10-22 (1/8 - 20 SA)

1020 cc collected @ 3:40P 6/22/76
Condensate ahead of Hx.
572 cc @ 1830 Hrs 6/22/76

13668

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: Performance
TEST ENGINEER: EK Moore
NAME OF RIG: 61, 61A
PROJECT & ENG. ORDER NO: C43-400-001B

SHEET: 1 OF
DATE: 6-22-76
TEST PLAN NO: C43-002 IV 4.5 Table V
MODEL NO: LLL HX II
PART NO: SVSK 90348-1
SERIAL NO:
OPERATORS: Creighton

Test Point	Time	H_2O Cir	H_2O Flow	H_2O Flow	K Factor	H_2O T in	H_2O T out	H_2O ΔT	H_2O P in	H_2O ΔP		Air Flow	Air Flow	Air T in	Air T out	Air ΔT	Air P in	Air P out	Air ΔP	Air in/H_2O in ΔT	DP In	DP out
No			CPS	#/Hr		°F	°F	°F	PSIG	"H_2O		#/Min	#/Hr	°F	°F	°F	"H_2O	"H_2O	"H_2O	°F	°F	°F
4D	2325	Sec	971	1009.35	1.0395	43.5	66.5	23.	24.3	60.5		22.76	1366	104.6	49.4	55.0	1.06	.28	.71	~~38.4~~ 61.7	57/62	47.5
4D	2335	Sec	970	1008.3	1.0395	43.5	66.5	23.	24.3	60.6		22.76	1366	104.6	49.5	54.9	1.05	.35	.71	61.7	57/62	47.5
4D	2345	Sec	970	1008.3	1.0395	43.4	66.5	23.1	24.3	60.5		22.76	1366	104.6	49.4	55.0	1.06	.35	.71	61.7	57/62	47.5

REMARKS
* Removed Cone Screen & Collector Ring in outlet duct Adapt. Per Your Telcon

13671

C

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: Performance
TEST ENGINEER: E K Moore
NAME OF RIG: 61, 61A
PROJECT & ENG ORDER NO.: C 43-400-000 B

SHEET 1A OF DATE 6-22-76
TEST PLAN NO. C43-002 ¶ 4.5 Table V
MODEL NO. LLL HX II
PART NO. SVSK 90348-1
SERIAL NO
OPERATORS Creighton

Test Point		Slurp Pin	Slurp Pout	Slurp ΔP		Steam H_2O Flow			Cond burett	Cond	Cond	Cond		Slurper Separator Orifice			CB
No		"H_2O	"H_2O	"H_2O		FR Scale	#/Hr		cc	cc/5 min	cc/min	#/Hr		Pin "H_2O	ΔP "H_2O		Hg/AB
4D		.28	-2.5	2.84		16.1	4.65		500/3 31	163	32.6	4.31		-4.6	.36		29.98
4D		.35	-2.6	2.88		16.1	4.65		500/3 43	157	31.4	4.15		-4.6	.36		29.98
4D		.35	-2.6	2.86		16.1	4.65		500/3 45	155	31.0	4.10		-4.6	.36		29.98
										Continued collection to 250cc = 7.783 min = 32.43cc min = 4.29 #/Hr							

REMARKS. F/R 102-22 (1/8-20 SA)
Started H2O Flow Steam 2130 Hrs 6/22 Shutdown ~~##~~ 0010 6/23 collected 580 cc ahead of HX (upstream)

13672

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: AIR PRESSURE DROP TEST DRY
TEST ENGINEER: E. MOORE
NAME OF RIG: C1
PROJECT & ENG. ORDER NO.: C43-400-001B

SHEET OF DATE 7-7-76
TEST PLAN NO C43-002 TABLE II
MODEL NO. LLL HX II
PART NO. SVSK 90348-1
SERIAL NO.
OPERATORS SANDBERG

TEST POINT		PIN	POUT	ΔP		TIN	TOUT		DPIN	DPOUT		FLOW	FLOW		CB
		"H_2O	"H_2O	"H_2O		°F	°F		°F	°F		#/MIN	#/HR		"HG AB
1		.37	.12	.23		79.5	78.7		11.5	12.5		11.66	699.6		29.77
2		.70	.23	.44		80.8	80.7		19.5	19.5		16.65	999.0		29.77
3		1.31	.54	.78		104.7	103.4		34.5	37.5		22.75	1365		29.75
4		1.63	.67	.96		86.7	80.3		35.0	35.0		26.66	1599.6		29.75

REMARKS

13571

HSF-175 1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: AIR PRESSURE DROP TEST. WITH SLURPER.

TEST ENGINEER: E. MOORE.

NAME OF RIG: C1

PROJECT & ENG ORDER NO.: C43-400-001B

SHEET ___ OF ___ DATE 2-8-76

TEST PLAN NO C43-002 TABLE II

MODEL NO. LLL Hx II

PART NO SVSK 90348-1

SERIAL NO.

OPERATORS SANDBERG

TEST POINT		PIN	POUT	ΔP		TIN	TOUT		DP IN	DP OUT		FLOW	FLOW		POUT SLURP	ΔP SLURP		FLOW SLURP	FLOW	PF/R		C.B
		"H_2O	"H_2O	"H_2O		°F	°F		°F	°F		#/MIN	#/HR		"H_2O	"H_2O		%	PPH	PSIA		
4		1.47	.50	.92		79.7	80.2		40.5	40.5		26.66	1599.6		-.1	.59		40	37.5	13.1		29.73
2		.61	.18	.43		79.0	78.5		29.5	29.5		16.63	997.8		-.65	.90		40	37.5	13.1		
1		.29	.08	.23		79.6	78.3		23.5	23.0		11.69	701.4		-.19	1.0		40	37.5	13.1		

REMARKS:

13570

APPENDIX D

ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS AND SYMBOLS

ave	average
BTU	British Thermal Units
°C	degrees Centrigrade
cc	cubic centimeters
cm	centimeters
d.a.	dry air
DA	double amplitude
db	decibels
°F	degrees Fahrenheit
g	gravity
g	grams
h	enthalpy
hg	mercury
hr	hour
Hz	Hertz
in	inches
k	kilo
K	degrees Kelvin
lat	latent
lbs	pounds
lr	leak rate
m	meter
max	maximum
min	minute
min.	minimum
mm	millimeters
N	Neinfons
N2	nitrogen
Pa	Pascals
psi	pounds per square inch
q	Btu/lb
Q	Btu/hr
R	universal gas constant
sec	second
sen	sensible
T	temperature
TDP	dew point temperature
t	time
V	volume
W	weight
$\sphericalangle$	angle
#	lb
%	percent
Δ	delta
ϵ	effectivenss
"	inches